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AND REPAIR TECHNOLOGY (DMART)
PROGRAM

VOLUME II: APPENDICES

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<p>In September 1985, the Assistant Secretary of Defense (Acquisition and Logistics) charged the Director, Maintenance Policy, to establish a maintenance research and development program aimed at stemming or reversing Department of Defense's escalating maintenance burden. The Defense Maintenance and Repair Technology (DMART) Program was developed in response to that charge.</p> <p>The DMART Program is designed to reduce the field maintenance cost of weapons systems by exploiting advances in repair technologies and processes, modernizing maintenance facilities and equipment, improving utilization of support resources, and promoting prime equipment reliability and maintainability improvements. Its principal features include systematic identification of opportunities for field maintenance improvements, selection and funding of projects to implement those improvements, and dissemination of maintenance technology information, including the results from implemented projects.</p> <p>Volume I of this report presents an overview of the DMART Program; describes why such a program is needed, and identifies the steps to implement the program. Volume II provides background material and supporting documentation for the DMART Program. Records</p>					
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APPENDIX A

DoD POLICY ON WEAPONS SYSTEM MAINTENANCE SUPPORT

This appendix reviews DoD policy and procedural guidance on the maintenance support of fielded weapons system and, where appropriate, identifies areas needing improvement. It is organized into two major sections.

The first section examines DoD policy and procedural guidance for weapons system maintenance. Although that guidance is very comprehensive, we find several weaknesses: (1) suitable measures have not been established for evaluating maintenance performance, (2) although responsibilities for monitoring the adequacy of maintenance support and for reviewing maintenance performance have been delegated to the Military Services, the Office of the Secretary of Defense (OSD) has not established any mechanism for review or oversight, and (3) current guidance, which is dispersed among many separate directives and instructions, lacks a coherent framework.

The second section evaluates criteria for, and indicators of, maintenance performance, subdivided into its two major components, maintenance engineering and maintenance production. With regard to maintenance engineering, the most important criterion is the maintainability achieved in weapons system design. We find that DoD policy, guidance, and emphasis on maintainability have significantly improved in recent years and that actions are underway to further improve the quantitative assessment of maintainability characteristics during weapons system design and development. In contrast, we find that materiel readiness, by itself, is not an adequate measure of maintenance performance nor are mission-capable rates. Although reported mission-capable rates for many weapons systems are high compared to the levels of a few years ago, field maintenance performance remains low in terms of productivity, efficiency, and quality. We present definitions and quantitative measures for those criteria as well as the available evidence based on maintenance data and previous studies.

POLICY GUIDANCE

DoD policy and procedural guidance related to weapons system maintenance are specified in several directives and instructions. The documents fall into two categories. One category addresses maintenance as an integral part of the weapons system acquisition process. The other addresses maintenance as a functional part of the DoD logistic system. The distinction between the two has declined over the years, with maintenance increasingly assuming a weapons system (as opposed to commodity) orientation, both by policy and in practice. While the maintenance function comprises both maintenance engineering and maintenance production, the former is the focus of the acquisition-related documents whereas the latter is the focus of the logistic system-related documents.

Acquisition System

DoD Directive 5000.39, "Acquisition and Management of Integrated Logistic Support for Systems and Equipment," 17 November 1983, establishes the requirement for life cycle management of integrated logistic support (ILS) for major systems and provides guidance for ILS policy applicable to nonmajor systems and equipment. It mandates an ILS program beginning at the inception of a major system acquisition program and continuing for the life of the system, with the primary objective to achieve system readiness requirements at an affordable life cycle cost. Early ILS activities are to influence the system design toward desirable support characteristics and to determine logistic support requirements. Subsequent activities are to develop, evaluate, and field the needed support resources. Throughout the acquisition cycle, ILS planning and resource decisions are to be based on the logistic support analysis (LSA) as specified in (military standard) MIL-STD-1388 but tailored to the specific acquisition program. The directive includes detailed procedural guidance and provides a checklist of ILS considerations for each acquisition process milestone. It also states that a "system management approach to ILS similar to that used in acquiring the system shall be maintained throughout the life cycle."

DoD Directive 5000.40, "Reliability and Maintainability," 8 July 1980, establishes policies and responsibilities for the reliability and maintainability (R&M) of defense systems, subsystems, and equipment. The directive states the objective of R&M activities to be fourfold: (1) operational effectiveness (increasing operational

readiness and mission success probability of fielded items); (2) ownership cost reduction (reducing demands for maintenance and logistic support, both on-equipment and off-equipment); (3) limitation of manpower needs (constraining operating and maintenance personnel to the skills and training expected to be available); and (4) management of information (collecting R&M data essential to acquisition, operation, and support management). The criterion for R&M activities is that each increment in cost or schedule spent on R&M must contribute significantly to these four objectives. The overall policy requires each R&M program to consist of a balanced mix of R&M engineering and accounting tasks, with reliability engineering focused on the prevention, detection, and correction of design deficiencies, weak parts, and workmanship defects; maintainability engineering focused on the reduction of maintenance and repair times, task complexity of maintenance actions, and special tools and test equipment; and R&M accounting focused on generating the information essential to acquisition, operation, and support management.

This directive defines a variety of R&M terms and measurement parameters; describes the management of R&M growth during full-scale development and initial deployment; and outlines the required monitoring of R&M in the acquisition process through demonstrations and tests, and at program milestone reviews. Importantly, it directs that R&M activities not be terminated with the fielding of a weapons system, but that:

- The acquiring agency continue to correct operational R&M deficiencies to ensure that R&M goals are achieved
- Specific offices be established to investigate and resolve operational R&M deficiencies of items no longer under the responsibility of an acquisition program
- Data collection systems be used for reporting measured values of system R&M parameters and for identifying operational R&M deficiencies
- Actions be taken to reduce the extent of "false alarms" at all levels of maintenance, including the provision of test facilities that are capable of diagnosing failures not found by conventional troubleshooting without environmental stress
- Specifications for spares, procurements, and modifications have the same R&M requirements as the original equipment, upgraded as necessary to correct R&M deficiencies.

Furthermore, the directive explicitly charges the Secretaries of the Military Departments with several responsibilities, including the following:

- Identifying R&M parameters applicable to each type of system they operate or acquire, defining measures for those parameters, and ensuring their data collection systems trace those parameters
- Establishing R&M requirements for each item, based on a defined item life profile including environmental conditions and skill levels of operator and maintenance personnel
- Analyzing operational R&M deficiencies to determine their causes and identifying tradeoffs between improvement of materiel and improvements of concepts or policies.

The directive also charges the Under Secretary of Defense for Research and Engineering (USDRE) with responsibility for the R&M of systems and equipment through all phases of the acquisition process; and the Assistant Secretary of Defense (Acquisition and Logistics), ASD(A&L), with responsibility for sponsoring "review of logistics support concepts and manning policies and revisions necessary to prevent recurrence of operational R&M deficiencies during all phases of the life cycle."

DoD Instruction 4000.26, "Post Production Support," 19 August 1986, provides detailed guidance on the implementation of the postproduction support policy established by DoD Directive 5000.39. It requires the Program Manager to prepare a complete postproduction support plan by the full-scale production decision point and the responsible system manager to update that plan as needed throughout the weapons system life cycle. The postproduction support plan is to document the resources and management actions required beyond the acquisition phase to meet readiness and sustainability objectives. It must include: assessment of the impact on the weapons system and the support system caused by production phaseout and technological obsolescence (based on a 10-year technological forecast); modifications to the ILS plan, product improvements, or other actions necessary to resolve those untoward impacts; and the strategy and resources required for sustaining engineering and effective configuration management. Importantly, the instruction charges the Secretaries of the Military Departments with the responsibility for reviewing postproduction support periodically throughout the life cycle of each major weapons system "as quantitatively as possible" and for assuring that adequate resources are planned, programmed, and budgeted for postproduction support. The ASD(A&L) is responsible for reviewing program compliance with postproduction

support plans during the acquisition phase and for reviewing implementation beyond the acquisition phase.

Logistic System

DoD Directive 4151.16, "DoD Equipment Maintenance Program," 23 August 1984, requires maintenance management to be oriented to weapons systems as opposed to commodity groupings and establishes the primary objective of DoD Components' maintenance programs to be the operational readiness of supported weapons systems. It requires data systems to be established for the collection of equipment reliability, availability, and maintainability data, materiel readiness performance data, maintenance work force performance data, and operating and support costs on all weapons systems. Included among its detailed procedural guidance are the following:

- Maintenance engineering activities shall participate in all phases of the system life cycle to reduce logistic support requirements and costs.
- Maintenance support costs shall be analyzed as part of LSA during the acquisition process and periodically throughout the system life cycle to identify areas requiring management action to keep costs within established baseline parameters.
- Programs shall be fostered to improve concepts, procedures, and processes in both the engineering and production facets of the maintenance function.
- Maintenance production operations shall be managed on the basis of total costs and oriented toward providing effective maintenance support at the least cost to achieve readiness objectives and sustainability.
- Maintenance tooling, equipment, test equipment, and skills for similar type workloads shall be standardized to the extent feasible among the Military Departments.

DoD Directive 4151.1, "Use of Contractor and DoD Resources for Maintenance of Materiel," 15 July 1982, requires that direct maintenance (organizational and intermediate) be performed, to the maximum extent possible, by combat and direct combat support activities (i.e., military personnel), but that interim contractor maintenance may be used with the introduction of new weapons systems until system design, R&M characteristics, maintenance procedures, and maintenance training have stabilized. Continued use of contractor personnel throughout the system life cycle is only permitted if there are shortages in skilled military

maintenance personnel and if such contractor personnel will provide wartime support in a combat zone. For other than combat and direct combat support materiel (e.g., support equipment), the source of direct maintenance support (DoD military or civilians, contractors, or host nation support) will be selected on the basis of: (1) need to maintain a training and rotational base for military technicians, (2) security implications, (3) timely availability of commercial sources or host nation support, and (4) cost effectiveness.

With respect to indirect or depot maintenance, this directive requires that a competitive commercial depot maintenance industrial base be established and maintained and be capable of expanding during mobilization. It states that organic depot maintenance capabilities shall be kept to the minimum required to ensure a ready source of technical competence and resources to meet military contingencies and requires the DoD Components to use a "decision tree," approved by the ASD(A&L), for assigning source of repair responsibilities and for determining the minimum organic resources required for mobilization. Unless the organic depot maintenance workload is justified by that decision tree, the directive puts a cap on its total (by commodity grouping, not by individual weapons system) by requiring that at least 30 percent of the gross mission-essential and all of the nonmission-essential workload shall be opened to nonorganic support (i.e., contractor depot maintenance).

Observations

We have three observations on DoD policy as it pertains to the maintenance support of fielded weapons systems.

First, current guidance is very comprehensive. It directs the Military Services to monitor the adequacy of weapons system maintenance support, to review maintenance performance and support costs, and to engage in sustaining engineering efforts and programs to reduce logistic support requirements and costs throughout the weapons system life cycle.

Second, current guidance assigns few responsibilities to OSD. Furthermore, once a weapons system is fielded, OSD has little visibility of the efficiency of maintenance support; the only data it routinely receives are mission capable rates.

Third, current guidance lacks a coherent framework. As currently structured, it is dispersed among many separate directives and instructions.

MAINTENANCE PERFORMANCE

To evaluate maintenance performance effectively, a coherent set of criteria and quantitative evaluation measures (indicators) is required. In recent years, the DoD has significantly enhanced the way it measures and evaluates maintainability in the acquisition of a new weapons system. In contrast, the actual performance of maintenance after the weapons system has been fielded (maintenance production) has traditionally been evaluated only in terms of operational readiness or derivative measures. The DoD has never articulated a comprehensive set of criteria and measures that would permit an evaluation of maintenance production in terms of other important aspects such as efficiency, cost, quality, or sustainability. That operational readiness is the first priority for maintenance production by policy (DoD Directive 4151.16), does not mean it should be the only consideration or criterion.

This section reviews the criteria and quantitative evaluation measures pertaining to both maintenance engineering and maintenance production, and provides an analytic framework for assessing the various factors that influence maintenance performance. We also summarize available maintenance data in terms of selected criteria (i.e., maintenance efficiency) in support of our observations.

Maintenance Engineering

Maintenance engineering is defined in DoD Instruction 4151.12, "Policies Governing Maintenance Engineering Within the Department of Defense," 19 June 1968, as:

... that activity of equipment maintenance which develops concepts, criteria and technical requirements during the conceptual and acquisition phases to be applied and maintained in a current status during the operational phase to assure timely, adequate and economic maintenance support of weapons and equipments.

Although this instruction is still in effect, the more recent DoD Directive 5000.40 is more specific in defining the objective of maintenance engineering as well as selected measures of maintainability. It defines R&M engineering as "that set of design,

development, and manufacturing tasks by which R&M are achieved"; and maintainability as:

The ability of an item to be retained in or restored to specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.

Further, it expands on the overall objectives of R&M activities by stating that maintainability engineering "shall reduce maintenance and repair time, number of tasks required for each preventive and corrective maintenance action, and the need for special tools and test equipment."

Historically, the concept of maintainability as a design requirement in the acquisition process dates back to the mid-1960's when specific guidance in the form of a military standard was first promulgated (MIL-STD-470, "Maintainability Program Requirements," 21 March 1966). That document, however, provided only qualitative measures. Although it included detailed design guidelines (summarized in Table A-1), the approach was to let the contractor "establish detailed maintainability design criteria determined from the repetitive system/equipment maintainability analysis." As a result, the basic measures used in practice consisted of repair time parameters such as mean time to repair (MTTR), critical percentile of cumulative frequency distribution of repair times [M_{\max} (95%) or (90%)], and "maintenance ratio" or "man-hour rate" (direct maintenance man-hours per flight hour or equipment operating hour). Methods for estimating the maintainability parameters for a weapons system during design and development were published in the form of a military handbook (MIL-HDBK-472, "Maintainability Prediction," May 1966). Guidance for verifying those predictions, for demonstrating that contractual maintainability requirements had been achieved, and for evaluating the impact of the operational environment on maintainability parameters was provided in MIL-STD-471, "Maintainability Demonstration," 15 February 1966 (subsequently revised in MIL-STD-471A, "Maintainability Verification/Demonstration/Evaluation," 27 March 1973).

As pointed out in MIL-STD-471A, the degree of maintainability achieved essentially depends upon the contractual requirements imposed and management's emphasis on maintainability. Contractual requirements, however, focused on repair times, especially those at the organizational maintenance level (on-equipment remove/replace tasks), so that in practice MTTR became virtually synonymous with

TABLE A-1

MAINTAINABILITY DESIGN GUIDELINES

<p>Reduce maintenance frequency by using:</p> <ul style="list-style-type: none"> ● Maintenance-free design ● Standard and proven design and components ● Simple, reliable, and durable design and components ● Fail-safe features to reduce failure consequences ● "Worst case" design techniques and tolerances that allow for use and wear throughout item life ● Adequate corrosion prevention or control features.
<p>Reduce maintenance downtime by designing for rapid and positive:</p> <ul style="list-style-type: none"> ● Prediction or detection of malfunction or degradation ● Localization to the affected assembly, rack, or unit ● Isolation to a replaceable or repairable module or part ● Correction by replacement, adjustment, or repair ● Verification of correction and serviceability ● Identification of parts, test points, and connections ● Calibration, adjustment, servicing, and testing.
<p>Reduce maintenance costs by designing for minimum:</p> <ul style="list-style-type: none"> ● Hazards to personnel and equipment ● Depot or factory maintenance ● Consumption rates and costs of repair parts and materials ● Erroneous indications of failure ● Personnel skills and quantities ● Need for special tools, support equipment, and facilities.
<p>Reduce maintenance complexity by designing for:</p> <ul style="list-style-type: none"> ● Compatibility between materiel and support equipment ● Standardization of design, parts, and nomenclature ● Interchangeability of like components, material, and repair parts ● Minimum maintenance tools, accessories, and support equipment ● Adequate accessibility, work space, and work clearances.
<p>Reduce maintenance personnel requirements by designing for:</p> <ul style="list-style-type: none"> ● Logical and sequential function and task allocations ● Easy handling, mobility, transportability, and storability ● Minimum numbers of personnel and maintenance specialties ● Simple and valid maintenance procedures and instructions.
<p>Reduce maintenance errors by designing for minimum:</p> <ul style="list-style-type: none"> ● Likelihood of undetected failure or degradation ● Maintenance waste, oversight, misuse, or abuse ● Dangerous, dirty, awkward, or tedious job elements ● Ambiguity in labeling or coding.

Source: MIL-STD-470, "Maintainability Program Requirements," 21 March 1966.

maintainability. Furthermore, management emphasis on maintainability was limited both by policy and in practice — supportability was ranked a distant fourth in management priority after performance, cost, and schedule. As a result, the maintainability achieved for new weapons systems often was inadequate. Particularly glaring was the lack of specification and evaluation of the diagnostic capability (fault detection and isolation) designed into a system. The resulting troubleshooting problems did not surface during maintainability demonstrations (which simply demonstrated accessibility and ability to remove/replace components following the procedures and with the tools documented in technical publications), but did appear after fielding.

Starting in 1980, the DoD undertook a number of actions to correct this deficiency. It revised acquisition policies to elevate supportability to a coequal level with cost, performance, and schedule (1980 revisions of DoD Directive 5000.1 and DoD Instruction 5000.2); it issued stricter policy on R&M (DoD Directive 5000.40); it revised MIL-STD-1388 to add more emphasis to front-end analysis and iteration of LSA throughout the acquisition cycle; and it developed methodologies for measuring, specifying, and evaluating testability (diagnostic capability) as a key component of maintainability. The revised MIL-STD-470A, dated 3 January 1983, is a much improved version of the original standard and includes two fundamental changes. One change is the emphasis on testability considerations as part of a maintainability program in recognition of the critical impact of testability on the achievement of maintainability design goals as well as life cycle costs. The other change is the emphasis on quantifying and evaluating maintainability not just at the organizational level but at all levels of maintenance. The revised standard now includes quantitative maintainability measures as well as design guidelines.

The related documents, MIL-HDBK-472 and MIL-STD-471A, are currently being revised to address the testability aspects, presumably building on a new testability standard (MIL-STD-2165, "Testability Program for Electronic Systems and Equipments," January 1985) and a new testability handbook (MIL-HDBK-XXXX, "Testability Analysis Handbook," March 1985 Draft). In the meantime, the Air Force is already operating under a revision to MIL-STD-471A (revision notice 2, dated 8 December 1978, applicable only to Air Force), which added 20 pages on procedures for evaluating and demonstrating diagnostic capabilities, including built-in-test (BIT) and external special-purpose test equipment (SPTE). That

addendum requires preparation of a "testability profile," showing the testability characteristics of each inserted or simulated failure, and computation of the following evaluation measures or "figures of merit":

- Proportion of failures detected
- Proportion of failures for which BIT and/or SPTE are effective in reducing fault isolation ambiguity
- Proportion of failures requiring only the use of BIT for isolation to a given ambiguity level
- Proportion of failures requiring the use of SPTE for isolation to a given ambiguity level
- Proportion of failures requiring some degree of manual testing [documented in the technical manual and using general-purpose test equipment (GPTE) as needed] to effect fault isolation
- Proportion of failures requiring some degree of manual testing not documented in the technical manuals to effect fault isolation
- Proportion of failures for which BIT and/or SPTE are capable of effecting fault isolation to a given level of ambiguity
- Proportion of failures for which BIT is effective in fault isolation by reducing ambiguity
- Proportion of failures for which SPTE is effective in fault isolation by reducing ambiguity
- Average ambiguity level when BIT is used for fault isolation
- Average ambiguity level when SPTE is used for fault isolation.

All of the above parameters, except the first, pertain to the three levels of fault isolation: "initial," defined as on-equipment fault isolation to a line replaceable unit (LRU); "secondary," defined as off-equipment fault isolation within an LRU to a shop replaceable unit (SRU); and "tertiary," defined as fault isolation within an SRU to a piece part.

In summary, DoD policy, guidance, and emphasis on maintainability have significantly improved in recent years. To the extent those improvements are enforced in the weapons system acquisition process, future weapons systems will either possess the requisite maintainability characteristics or exhibit maintainability shortcomings that have been quantitatively assessed and purposefully

accepted based on tradeoffs with cost, performance, and schedule. If such shortcomings are identified in a timely manner, steps can be taken to compensate for them. In the past, both the measurement and evaluation of maintainability were inadequate. As a result, many of today's weapons systems exhibit poor maintainability characteristics, most of which have received little visibility and attention. In turn, those characteristics are also a major contributing factor to inefficient maintenance performance, as discussed next.

Maintenance Production

Maintenance production is defined in DoD Instruction 4151.12 as:

... that activity of equipment maintenance which involves the physical performance of those actions and tasks attendant to the equipment maintenance function for servicing, repairing, testing, overhaul, modification, calibration, modernization, conversion, inspection, etc. The accomplishment of these tasks is normally carried out at three levels comprised of organizational, intermediate and depot maintenance.

Virtually the same definition is contained in DoD Directive 4151.16, which also defines weapons system operational readiness as the primary objective of the maintenance mission. That directive, however, fails to provide any criteria or quantitative evaluation measures for maintenance performance other than the following statement:

Maintenance production operations shall be managed on the basis of total costs... and shall be oriented toward providing effective maintenance support at the least cost to achieve readiness objectives and sustainability.

While there is firm agreement that the purpose (and, therefore, the primary objective) of maintenance production is to achieve and sustain combat readiness, there is less agreement about the precise criteria for, and associated evaluation measures of, combat readiness or the materiel readiness component of combat readiness. In the following subsections, we first review how readiness is currently measured, including the contribution of maintenance to materiel readiness, then we outline an alternative assessment methodology that focuses on maintenance production.

Measurement of Materiel Readiness

Three standard methodologies are used in the DoD for measuring or assessing materiel readiness. They are summarized in Table A-2.

TABLE A-2

STANDARD READINESS MEASURES

Unit readiness	<p>C1 (fully ready): A unit fully capable of performing the mission for which it is organized or designed.</p> <p>C2 (substantially ready): A unit has minor deficiencies which limit its capability to accomplish the mission for which it is organized or designed.</p> <p>C3 (marginally ready): A unit has major deficiencies of such magnitude as to limit severely its capability to accomplish the mission for which it is organized or designed.</p> <p>C4 (not ready): A unit not capable of performing the mission for which it is organized or designed.</p> <p>C5: Applies to weapons systems in overhaul.</p>
Materiel condition	<p>FMC (fully mission capable): When all mission-essential subsystems are installed and operating as designated by the Service.</p> <p>PMC (partial mission capable): When systems can perform one or more but not all assigned missions because one or more of their mission-essential subsystems are inoperative for maintenance or supply reasons.</p> <p>MC (mission capable): The sum of FMC and PMC.</p> <p>NMC (not mission capable): When none of the assigned missions can be performed either due to maintenance (NMCM) or supply (NMCS).</p>
Operational availability	<p>$A_o = \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}} = \frac{\text{MTBM}}{\text{MTBM} + \text{MDT}}$, where:</p> <p>MTBM = mean time between maintenance</p> <p>MDT = mean down time = MTTR + MLDT + MADT</p> <p>MLDT = mean logistics delay time (awaiting parts)</p> <p>MADT = mean administrative delay time</p> <p>MTTR = mean time to repair.</p>

The Military Capability Reporting System, established by Joint Chiefs of Staff (JCS) *Memorandum of Policy No. 172*, 20 April 1971 (revised 1 June 1982), comprises two types of reports, the Commander's Situation Report and the Unit Status and Identity Report (UNITREP). The latter is a DoD-wide standard reporting system under which all combat, combat service, and selected combat service support units report their combat readiness in terms of "C" ratings. Combat readiness (the ability of a unit to perform its assigned missions or functions) is conceived as the composite of personnel readiness (determined by the availability of required personnel and their training) and materiel readiness (determined by materiel on-hand,

materiel condition, and logistics support). The overall unit rating equals the lowest rating for any of the four individual resource areas (personnel, equipment/supplies on-hand, equipment readiness, and training). The issue of unit readiness or capability reporting is complex and has been examined in numerous studies. A recent report by the General Accounting Office (GAO) provides a good overview of those studies and the problems involved.¹ Although the current system may have some shortcomings, it is one of the major tools for monitoring trends in combat readiness. It is, however, ill-suited for the purpose of monitoring maintenance performance.

The second methodology is the Materiel Condition Reporting System established by DoD Instruction 7730.25, "Materiel Condition Reporting for Mission-Essential Systems and Equipment," 22 May 1980. Materiel condition status is measured in terms of the percentage of time that materiel is either fully mission capable (FMC), partial mission capable (PMC), or not mission capable (NMC). For reporting purposes, the mission capable (MC) rate is the sum of FMC and PMC rates; further, the NMC rate is subdivided by cause, either maintenance (NMCM) or supply (NMCS). DoD Instruction 7730.25 requires the Military Services to establish MC goals for all mission-essential materiel, to collect and report the MC and NMC rates actually achieved, to identify the top-five problems at the subsystem level that are causing nonachievement of goals, and to develop and implement remedial actions necessary to correct those problems.

The MC rates are viewed as the key measure of materiel readiness, and the Military Services attach great importance to meeting stated readiness goals. Although the MC rate provides some indication of one aspect of maintenance performance — maintenance effectiveness — it is an incomplete and imprecise measure. To illustrate, units frequently view their reported MC rates as a "report card." This invariably results in unproductive maintenance actions, such as cannibalization in order to consolidate the number of "holes" (missing or inoperable LRUs) on the smallest number of weapons systems possessed. Furthermore, it stresses the reporting of MC rates rather than FMC rates. Under certain circumstances, it may be preferable to have a portion of a unit's multicapable weapons

¹U.S. General Accounting Office, *Measures of Military Capability: A Discussion of Their Merits, Limitations, and Interrelationships*, NSIAD-85-75 (Washington, D.C.: U.S. General Accounting Office, 13 June 1985).

systems in FMC status and the rest in NMC status rather than all in PMC status. Although this reporting system is a good management tool, it is inappropriate for measuring maintenance performance.

The third methodology is based on the concept of operational availability (A_o): the probability that equipment will be operational at any given time in the operational environment as defined by the equation shown in Table A-2.² This analytic approach to measuring materiel readiness is, of course, used extensively in weapons system design and ILS planning, including LSA, level of repair analysis, and initial provisioning. It is also used during the operational portion of the weapons system life cycle, either as a supplement to or in lieu of formal MC reporting. While the MC rate is primarily an operational measure of materiel readiness, A_o is a logistics measure of materiel readiness. To illustrate the differences between the two measures, low operating hours tend to inflate MC rates but have less impact on A_o . Furthermore, the computed A_o for a weapons system typically is less than the reported MC rate. On a trend-line basis, however, the two are comparable in the sense that an upward trend in A_o over time is consistent with an upward trend in the MC rate. Like the MC rate, A_o is a poor measure of maintenance performance; it provides one index for maintenance effectiveness but no visibility of other aspects of maintenance performance.

In summary, the three standard methods used in the DoD for measuring materiel readiness are of limited use for measuring or evaluating maintenance performance. Yet, those are the only indicators of the maintenance function available at the OSD level.

²This is the equation for A_o adopted in one form or another DoD-wide. The North Atlantic Treaty Organization (NATO) has adopted a different convention analogous to that used in private industry, where availability is measured in terms of the ratio of actual to scheduled available time. This translates into $(MTBM - MDT)/MTBM$. The net effect is that United States availability figures exceed the corresponding NATO figures for identical availability conditions because the latter are more sensitive to downtime. For example, if downtime is as high as the interval between mission-essential corrective maintenance actions, operational availability would be 50 percent in U.S. terms, but 0 percent in NATO terms.

Measurement of Maintenance Performance

The absence of valid maintenance performance measures inhibits a quantitative assessment of maintenance production in the DoD. This void has several serious consequences.

First, it frustrates the implementation of DoD policy that requires the Military Services to monitor maintenance performance.

Second, it creates a perception in the maintenance community that quality of maintenance is a low-priority item within the DoD. If materiel readiness is the single criterion, then maintenance personnel will do whatever is necessary to keep systems operational, even if it requires the use of inefficient procedures and excessively high supply support costs.

Third, and most importantly, it establishes a major impediment to the systematic identification and resolution of maintenance deficiencies. Thus, opportunities to effect improvements cannot be exploited.

To correct these shortcomings, several actions are required: (1) a comprehensive set of criteria and indicators should be developed to measure maintenance performance in all its aspects, (2) current maintenance data collection systems should be enhanced by the Military Services to measure maintenance performance in terms of the new criteria and measures, and (3) a formal review mechanism should be instituted for the Military Services to report their quantitative evaluation of maintenance performance, identify opportunities for improvements, and specify the actions planned, including the resources required, to effect those improvements.

As a start, the following outline presents our preliminary thoughts on selected criteria and evaluation measures for such a comprehensive maintenance performance assessment system. We believe these criteria, defined for each maintenance level, capture the relevant aspects of maintenance performance:

- *Support effectiveness*, defined as the extent to which weapons system support satisfies mission objectives. This criterion is emphasized by current policy, but it incorporates all factors contributing to support rather than only maintenance. It is also the single criterion that is closely monitored by the Military Services, with standards or goals specified by operational commands for most of the measures of support effectiveness. Those

measures include FMC, PMC, NMCS, and NMCM rates; mission abort rates and maintenance-related mishap rates; and turnaround time parameters.

- *Maintenance productivity*, defined as the relationship between maintenance input (resources) and output (weapons system operating hours or sorties). Associated measures are estimated during the acquisition process but are not accurately tracked after fielding. Measures of productivity are neutral in the sense they cannot be interpreted without a reference baseline; they include direct maintenance man-hours per operating hour and support cost per operating hour.
- *Maintenance efficiency*, defined as the extent to which maintenance is performed without wasting available resources (labor hours, materiel, support equipment). Measures include personnel utilization [ratio of maintenance man-hours spent to those available (percent job diversions); labor productivity (ratio of standard task times to actual time spent); cannibalization statistics; and unnecessary removal statistics (percent removals that are serviceable, unnecessary removals per operating hour, ratio of mean time between removals and mean time between failures, percent man-hours expended on unnecessary removals)].
- *Maintenance quality*, defined as the extent to which maintenance restores the prime equipment to serviceable condition without degrading its performance and R&M characteristics. Measures include maintenance-inflicted damage rate; repeat repair rate; and percent of "bad actors" (percentage of items passing tests at one level but failing tests at the next lower level), or failed system check rate.
- *Maintenance dependability*, defined as the extent to which maintenance workload is performed at the lowest level authorized without outside assistance while meeting mission requirements. Measures include percentage of maintenance workload performed by nonorganic support activities/personnel, percentage performed by higher maintenance echelons than authorized, and maintenance backlogs (awaiting parts, awaiting maintenance).
- *Maintenance flexibility (sustainability)*, defined as the extent to which maintenance units are capable of performing variable workloads under different conditions, including wartime scenarios. Measures include percent nondeferrable maintenance workload performed, postexercise duration to catch up, and selected measures for the other criteria under exercise or simulated wartime conditions.

Maintenance Data

The maintenance data collection systems used by the Military Services and the quality of data they provide have been the subject of criticism for many years.

Considering the volume of data collected and the wide variety of demands made upon those systems, their shortcomings are both understandable and difficult to overcome.

To illustrate the nature of the shortcomings, many of the maintenance performance measures that we outlined above are either not available or inaccurate, unless a special effort, outside the "standard" system, is undertaken. Such efforts have often become standard practice with the introduction of a new weapons system, whereby a separate, dedicated maintenance data base and collection system is established, often contractor-operated. Those efforts, however, tend to be discontinued after a few years. Thus, for the older weapons systems in the DoD inventory, the available maintenance data often are unreliable.

APPENDIX B

MAINTENANCE REVIEWS OF FIELDDED WEAPONS SYSTEMS

BACKGROUND

The shortfalls in logistic support of fielded weapons systems have been the focus of numerous studies. Some of the studies recommended changes to policy, while others stressed a variety of management improvements. Many concluded that a more thorough and formal logistic review process was needed for weapons systems in the operational phase of their life cycle. They found that although each of the Military Services has implemented a comprehensive weapons system review as part of follow-on operational test and evaluation, once that period passed management has little visibility of the efficiency of the logistic support posture for a weapons system nor does it place emphasis on it.

Periodic reviews, such as the Air Force's *Logistics Program Assessment Review* and similar review processes in the other Military Services, typically do not address maintenance performance in sufficient detail. Rather, they tend to focus on such issues as product improvement programs and funding for major spare components. In recognition of that fact, the Air Force recently initiated a more thorough support analysis and planning process, known as the "weapon system master plan" (see Appendix E for more detail on this plan). This initiative is a most promising one, but the details (such as quantitative measures for assessing the effectiveness and efficiency of maintenance performance) have not yet been defined, the process has not yet been institutionalized, and the results are difficult to predict at this time.

Defense Resource Management Study

The Defense Resource Management Study was commissioned by Secretary of Defense Brown in response to a request by President Carter in September 1977. The

final report was submitted February 1979 and contains the following observations that are germane to the support topic of fielded weapons systems.¹

On the subject of ownership considerations in the acquisition process (p. 38):

The recent increased emphasis on support in the acquisition process should be continued, and the range of "ownership" issues considered should be broadened, thus helping to:

- Increase the probability that design capabilities will be realized;
- Ensure that new systems are supportable (at acceptable cost);
- Exercise control over and, where possible, reduce support costs — because unnecessary expenditures on support reduce the total capability that can be bought with limited Defense budgets.

On the subject of need to follow-through in the deployment phase (p. 41):

... there will always be limits on how much can be learned through "paper" analyses, including support analyses, and limited testing of only the primary hardware that is accomplished during full scale development. Actual system availability and support effectiveness is known only when the new system is operated and supported in field units by normally trained and assigned personnel under the actual concept of system employment. This point is not usually reached until two or more years after the last DSARC [Defense System Acquisition Review Council] Review. Although much of the production and support funds are not yet committed, and deficiencies could still be corrected by prompt action, there is no requirement or institutional mechanism for a full system analysis and review of "hard" information.

In fact, the existing institutional mechanisms impede integrated support management at this critical juncture. The funds for sustaining engineering, modifications, personnel training, spares provisioning, and other support elements are separately programmed and managed by function across weapon system lines. Key ILS assumptions can be altered in the programming process... without specifically assessing the impact on the newly fielded system or providing for compensating changes in other elements of the system support plan.

The report includes the following recommendation (p. 42):

- A full integrated support evaluation should be conducted when adequate experience is accumulated on the fielded equipment and on the effectiveness of its full training and support system. The services must establish institutional mechanisms that provide priority management and funding for prompt, efficient correction of deficiencies in availability and support of newly

¹Donald B. Rice (Study Director), *Defense Resource Management Study — Final Report* (Washington, D.C.: U.S. Government Printing Office, February 1979).

fielded systems. MRA&L [Manpower, Reserve Affairs and Logistics] and PA&E [Program Analysis and Evaluation] should conduct follow-on support reviews of selected recently fielded systems until adequate attention is focused on these problems. These reviews should trigger issue papers where necessary in the combined program/budget review proposed in Chapter I. They could be conducted by a SAIG [Support Analysis Improvement Group] or similarly constituted OSD panel.

Although the Weapons Support Improvement Group, which was subsequently established in OSD, has followed-up on several of the other recommendations of this report, thus far it has not conducted any follow-on support reviews nor established the institutional mechanism requiring the Military Services to conduct such reviews and report the results to OSD.

Defense Science Board Study

The Defense Science Board (DSB) 1981 Summer Study was commissioned by the Under Secretary of Defense for Research and Engineering (USDRE) to assess the impact of high-performance systems and high technology on: (1) operational availability of equipment, (2) skill and training requirements of operators and maintainers, (3) cost and affordability of adequate quantities of equipment, and (4) cost of support. The DSB report, submitted to the Secretary of Defense in April 1982, contains the following observations on weapons system support.²

On the subject of system readiness review during acquisition as well as after deployment:

... Senior acquisition executives in both government and industry maintain a strong interest in major weapon systems during their development and production. During these phases, a disproportionate emphasis is often placed on performance and cost, while actions required to ensure the readiness of the system once it is fielded do not enjoy the same attention. ... Once the system has attained an initial operating capability, the situation rapidly worsens. The interest in our major weapon systems by senior managers often drops markedly at this point, perhaps due to the misguided notion that the most critical phase of the system's life cycle has just been passed. The fact is that the most difficult, and one of the least glamorous phases, lies immediately ahead. Attaining a high level of operational readiness for advanced weapon systems requires continual emphasis on such things as personnel selection, training, spare parts, and the logistic support organization, test equipment, and simulators.

²*Report of the Defense Science Board 1981 Summer Panel on Operational Readiness With High Performance Systems* (Washington, D.C.: Office of the Under Secretary of Defense for Research and Engineering, April 1982).

Attention to these critical areas must be focused early in the program and it must persist well into the operational lifespan of each system. [p. 3-1]

Although the essence of an effective system readiness advocacy program would establish the program manager as the key element, other agencies must participate as well. For example, the military departments should conduct comprehensive system readiness reviews, at least semi-annually. These reviews, using consistent measures of system readiness, should be conducted for all major weapon systems. . . . If the military departments perform their job effectively, there should be no need for greater involvement by the Office of the Secretary of Defense than under current arrangements, although it does appear appropriate to delineate responsibilities within the OSD staff . . . to ensure fully coordinated and focused support to the program readiness advocate. Considering the importance of improving system readiness, it is also recommended that each military department brief the top managers in OSD at least annually. This briefing should highlight the actual and projected operational readiness factors for each major weapon system, the corrective actions taken, and the assistance required from the Office of the Secretary of Defense. [p. 3-3 and 3-4]

. . . the Panel also addressed itself to what might be done to improve the readiness of systems which are already in the field. . . . The Panel recommends that the Services consider the formation of "readiness tiger teams" to review the systems which exhibit poor readiness to determine the major causes of the low readiness and to recommend corrective action. . . . With regard to deployed systems, the Panel found in several cases that perhaps 20% of the line replaceable units were accounting for 70-80% of the actual replacements. However, it did not appear that there was any concerted effort to identify these high failure rate items and to concentrate resources on early improvements in their reliability. Consequently the readily obtainable increases in availability, and reductions in maintenance efforts and spares consumption, are never achieved. [p. 3-12]

The report provided valuable ammunition for the "quality versus quantity" debate then ongoing in Congress by rejecting the notion that current-generation weapons systems are more complex than previous-generation systems and, therefore, more difficult and costly to maintain, less operationally available, and less combat ready. Rather, the Panel concluded that system performance has been increasing faster than either procurement cost or support cost and that increasing complexity is not necessarily related to declining readiness. One of the Panel's recommendations was that the ASD(MRA&L) be "responsible for system readiness in DoD." However, as Assistant Secretary Korb pointed out in a memorandum filed with the DSB report, he was already the readiness advocate in both the Planning, Programming, and Budgeting System and the DSARC, but during the acquisition

cycle the USDRE controls the funds and program actions that influence R&M, support, and training equipment design and procurement:

... the separation of advocacy from responsibility and authority is probably not the most effective long term arrangement particularly at the front end of the weapon programs. Some improvement in definition of responsibilities and authority needs to be sought. This may be even more important in the Services than OSD. [Korb Memorandum for the Deputy Secretary of Defense, 20 May 1982.]

These conflicts in responsibility have continued to persist even after the OSD reorganization that resulted in the establishment of a new position, ASD(A&L), in 1985. However, from an organizational point of view, the 1986 redesignation of the Deputy Secretary of Defense as the Defense Acquisition Executive has reduced this particular problem, and the recent statutory establishment of the USD(Acquisition) may resolve it completely.

The DSB report was approved by Secretary Weinberger in June 1982. With the exception of a follow-on study (popularly known as the "IDA-OSD R&M Study"), none of the many recommended actions was followed up under the notion that most were consistent with the ongoing efforts to implement the "Carlucci initiatives" under the Acquisition Improvement Program. Those initiatives, however, did not address the issue of postfielding reviews of weapons system supportability.

RAND Study

A recent report by the RAND Corporation provides a number of suggestions for improving the weapons system acquisition process, consolidating the findings from numerous RAND studies over the last three decades.³ One of its recommendations is to introduce a formal review of fielded weapons systems at the OSD level to focus more attention on upgrading existing weapons systems as an alternative to developing new ones. Although the report does not explicitly refer to incorporating maintenance support issues in such a review, the detailed data that RAND recommends be collected would also enable evaluation of maintenance support and determination of maintenance improvements as part of such a review. A quote of the pertinent section of the report follows (pp. 44-45):

³Michael Rich, Edmund Dews, and C. L. Batten, Jr., *Improving the Military Acquisition Process - Lessons from RAND Research*, RAND Report R-3373-AF/RC (Santa Monica, California: The Rand Corporation, February 1986).

The increasing importance of upgrading fielded weapon systems as the most cost-effective means of modernizing U.S. forces requires additional changes in the acquisition process. The Services need to collect engineering data in realistic operational settings throughout a system's operational life. This special extended form of "operational testing" should explore the system's suitability for combat in the full-range of plausible conflict environments. Because its purpose is to identify equipment deficiencies and needed enhancements of subsystem and system capabilities, this type of testing and analysis calls for much more active and direct participation by contractor design engineers during the system's operational phase than has been common in the past.

In the acquisition process, the last review by the Defense Systems Acquisition Review Council is now usually scheduled to occur *before* the beginning of high-rate production. Even with the introduction of a phased acquisition strategy — which would mean that substantial IOT&E results would be available *before* rather than after this review — this is still too early in the life-cycle of a modern weapon system to abandon controls at the level of the Office of the Secretary of Defense. There is therefore a case for introducing additional formal reviews — perhaps a DSARC IV — to stimulate and assess upgrade options and to review and approve proposals for major modifications and retrofits.

The emphasis on system upgrading should be formalized as a major feature of force modernization strategy. Upgrades should be explicitly encouraged in parallel with and in competition with new system programs. In many circumstances, this kind of "virtual" competition promises greater benefits than the usually much more costly method of supporting two prime contractors through full-scale development. It also increases flexibility in adapting to many of the uncertainties that surround the acquisition of defense systems.

The RAND report is reportedly receiving a lot of interest within OSD as part of the pending reforms inspired by the Packard Commission (the President's Blue Ribbon Commission on Defense Management) and legislated by the Congress (DoD Reorganization Act of 1986). The final report of the Packard Commission,⁴ however does not address the issue of postdeployment weapons system reviews. The idea of a "DSARC IV" is not new; it has been recommended by various studies, most recently the DSB 1984 Summer Study.⁵

⁴David Packard (Chairman), *A Quest For Excellence — Final Report to the President* (Washington, D.C.: President's Blue Ribbon Commission on Defense Management, June 1986).

⁵Final Report of the 1984 Defense Science Board Summer Study on Upgrading Current Inventory Equipment, *Improved Defense Through Equipment Upgrades: The U.S. and Its Security Partners* (Washington, D.C.: Office of the Under Secretary of Defense for Research and Engineering, November 1984).

PILOT APPLICATION

The key to successful maintenance reviews of fielded weapons systems unquestionably lies with the data examined during those reviews. As a means of illustrating the data that we believe necessary to such a review, we have prepared a draft Maintenance Review Data List (presented subsequently in this appendix) assuming that the system being reviewed is the F-15 aircraft. (For other categories of weapons systems, much of the data will, of course, need to be tailored somewhat.)

The draft list solicits information on those parameters that appear to be most useful for identifying opportunities for maintenance improvements. Some of the data, however, may not be readily available or would be too expensive to develop. The draft list is, therefore, intended as a trial approach to find out which data are available, how accurate the available data are, and on what parameters are the most meaningful and practical indicators. For future applications, the list will be refined accordingly.

MAINTENANCE REVIEW STRUCTURE

The draft list is structured in terms of a number of overall evaluation criteria, followed by a more detailed examination of each of the factors affecting maintenance performance. The overall maintenance criteria and their definitions are as follows (the associated indicators are specified in the list):

- *Maintenance productivity*, defined as the empirical relationship between maintenance input (resources) and output. Total factor productivity is the combined outcome of resource-specific productivity ratios (labor, material, and capital) that are interrelated. By itself, productivity is a neutral parameter that can only be interpreted given a frame of reference for comparison.
- *Support effectiveness*, defined as the extent to which the output of maintenance activity satisfies mission objectives. Because of its mission impact, the Military Departments monitor maintenance effectiveness closely, with standards or goals specified by operational commands for most of the measures of maintenance effectiveness.
- *Maintenance efficiency*, defined as the extent to which maintenance is performed with a minimum of waste of available resources (labor, material, equipment). To the extent maintenance units are sized for wartime maintenance workloads that are multiples of the peacetime workload, some measures of maintenance efficiency are by necessity low in peacetime

unless peacetime workload comprises tasks not performed in wartime (e.g., training).

- *Maintenance quality*, defined as the extent to which maintenance restores the prime equipment to fully operational condition without degrading its performance, reliability, or maintainability characteristics.
- *Maintenance dependability*, defined as the extent to which maintenance workload is performed at the lowest level authorized in accordance with schedule requirements and without outside assistance.
- *Maintenance flexibility*, defined as the extent to which maintenance units are capable of handling variable workloads under different conditions.

The list includes one or more measures for each of these six criteria.

Following the overall maintenance criteria, the draft list solicits more detailed data on each of the following maintenance factors:

- Prime equipment reliability and maintainability (R&M) characteristics, including built-in test (BIT)
- Manpower, personnel, and training
- Repair process technology
- Maintenance facilities and equipment
- Technical information and maintenance aids
- Management, decision support, and control systems.

The final two sections provide for comments and suggestions by the System Manager. That feedback is critical if the maintenance review process is to be successful.

INSTRUCTIONS

Because of the different aircraft configurations and missions, data should be provided separately, if possible, for each model [F-15 A/B, F-15 C/D, Multistage Improvement Program (MSIP) aircraft, and anticipated values for the F-15E] and mission (combat squadrons versus training squadrons) combination. Data should be provided on a unit basis, i.e., the average value and range of each parameter for a unit (wing or squadron, whichever is more appropriate) based on the available data for all comparable units (same aircraft configuration and mission).

The respondent to the Maintenance Review Data list should indicate where requested data are not readily available and should provide the best estimate if possible. Where data are not available in terms of the requested breakout, the respondent should provide similar data at whatever breakout is available. Where available data are known to be incomplete or inaccurate (e.g., because of limitations to the Maintenance Data Collection System or operational practices), the answer should include an estimate, if possible, of the data accuracy (i.e., how far the presented data may be off, percentage-wise, from the actual values).

MAINTENANCE REVIEW DATA LIST

The list is organized into 14 categories of maintenance-related data in accordance with the previously described structure.

1. Maintenance Productivity

a. Provide the following productivity measures:

- Maintenance ratio measured in maintenance man-hours per flying hour (MMH/FH), broken out by organizational (O), intermediate (I), and depot (D) levels, and total.
- MMH/sortie (same breakout as above).
- Support cost per flying hour (identify the model used and the support costs elements that are included and excluded).
- Trend lines for each of the above measures.

b. Describe the factors or actions that are responsible for changes in these productivity measures over time. Compare earlier estimates (base line and independent cost estimate at Milestone 3 of the acquisition program) with current values.

2. Support Effectiveness

a. Provide the following effectiveness measures and compare each with stated standards or goals. If no standards or goals have been set, provide reference data in the form of same parameter data for other tactical aircraft.

- Mission Capable (MC) rates: fully (FMC), partial (PMC), and not mission capable (NMC) rates; NMC rate broken down into supply, maintenance, or both (NMCS, NMCM, NMCB).
- Trend-line graphs for FMC, PMC, NMCS, and NMCM.

- Mishap rate; percentage due to maintenance or maintenance-related; trend data.
 - Mission abort rate (ground and air); trend; correlation of air abort rate with projected mission abort rate using Mission Completion Success Probability Models.
 - Break rate (percent aircraft returning from mission with inoperable systems); trend.
 - Fix rate (percent of break-rate aircraft returned to FMC status within 4 hours; within 8 hours; within 12 hours; within 24 hours); trend.
 - Mean time to return to service or turnaround time (including fueling, servicing, reconfiguring, weapons loading, and on-equipment maintenance).
 - Percent accomplishment of scheduled sorties; trend.
- b. Describe top five problems (subsystem level) impeding achievement of higher FMC rate (in accordance with DoD Instruction 7730.25). Show the change in composition of top five problems over time.
 - c. Identify and describe the actions taken in the past or planned for the future to improve support effectiveness as measured by the above indicators; actions programmed to resolve "top five" product deficiencies; and impediments to the successful implementation of planned actions.
 - d. Describe rules for determining FMC, PMC, and NMC rates and discuss the operational implications of a low FMC/PMC ratio for multimission aircraft (the high FMC/PMC ratio reported for the F-15 in recent years is an exception).

3. Maintenance Efficiency

- a. Provide the following efficiency measures:
 - Maintenance personnel utilization at O and I level expressed in terms of MMH spent/MMH available. [For the denominator, use direct maintenance man-hours (DMMH) available, as determined by on-hand personnel, net of indirect time, scheduled on-the-job-training (OJT), and other maintenance job diversions. Alternatively, use DMMH based on Air Force standards.]
 - Maintenance personnel productivity at O and I level expressed in terms of standard task times/MMH spent. In the absence of task standards (work measurement program), use data from

Development/Operational Test and Evaluation, task and skill analysis, and Maintenance Demonstrations, adjusted for configuration changes.

- Support equipment utilization at O and I level expressed in terms of the fraction of time per shift each major item of support equipment [e.g., flight line test sets, O-level shop equipment, I-level automatic test equipment (ATE), engine test stand] is utilized.
- Ratio of O-level removal rate to prime equipment failure rate, expressed in terms of mean time between removals (MTBR) over mean time between failures (MTBF), $MTBR/MTBF$. Break the system level ratio out by major subsystem (e.g., avionics, propulsion, electromechanical, other).
- Percentage distribution of O-level removals by cause: preventive maintenance in accordance with Technical Order (TO) (i.e., fixed time limits or on-condition monitoring); confirmed failures; accessibility reasons; cannibalization; and other (= unnecessary removals). Provide the system level distribution as well as the distribution by major subsystem.
- Cannibalization workload expressed in terms of: cannibalization removals per FH and per sortie; cannibalization man-hours per removal; cannibalization man-hours as percentage of total O-level corrective maintenance man-hours.
- Unnecessary removal workload expressed in terms of: unnecessary removals per FH and per sortie; unnecessary removal man-hours as percentage of total O-level corrective maintenance man-hours; bench check serviceable (BCS) rate at I-level; percent I-level maintenance man-hours spent on BCS items; percent of I-level ATE hours spent on BCS items.
- Similar cannibalization and unnecessary removal statistics for the I level: percentage distribution of I-level removals [of shop replaceable units (SRUs) from line replaceable units (LRUs)] by cause; cannibalization man-hours as percentage of I-level maintenance man-hours; unnecessary SRU removal man-hours spent as a percentage of I-level maintenance man-hours; Retest Okay (RTOK) rate at D level; percent I-level MMH spent on RTOK items; percent of D-level ATE hours (for F-15 items) spent on RTOK items.

- b. Identify steps taken to reduce cannibalization and unnecessary removal rates since 1980; identify results achieved from those steps; and describe impediments to further reduction in those rates.
- c. Are cannibalization and unnecessary removals treated as key indicators of maintenance efficiency? Are there any goals or standards? Could they be reduced cost-effectively? What are the causes? What are the improvements planned for the Multistage Improvement Program (MSIP) and F-15E?

4. Maintenance Quality

- a. Provide the following quality measures:
 - The percent of faulty items not detected and removed from the system (O level) or LRU (I level), but left installed because maintainers believe they are serviceable. (This type of measure may not be available through standard maintenance data collection.)
 - The percent of maintenance actions at O and I levels that result in damage and need for repair.
 - Repeat repair rate expressed in terms of system, subsystem, LRU, and SRU repairs that must be repeated to correct the same failure symptom that the first repair was supposed to correct.
 - Extent of reduction in MTBF over time at system, subsystem, and LRU levels.
 - Failed system check rate: percent of LRU replacements that do not pass system checkout (O level); percent of SRU replacements that do not pass LRU checkout (I level).
 - Percent "bad actors": percent of LRUs (SRUs) that are known to cause "vertical testability" problems; i.e., passing tests at one level (I and D level, for example), but not passing tests at the next lower level (O and I level, respectively).
- b. What indicators are used to monitor maintenance quality? Are there any specific goals or requirements?
- c. To the extent the above measures indicate a quality problem, what corrections are planned? To what causes is the problem attributed [personnel proficiency, training, TOs, management, prime equipment design characteristics including built-in test (BIT), support equipment including ATE and test program sets (TPSs), other]? On

what studies is this attribution based? What results can be expected from the planned corrective actions?

5. Maintenance Dependability

a. Provide the following dependability measures:

- Not Repairable This Station (NRTS) rate: percent of maintenance actions at O level and I level not accomplished at the lowest level authorized and evacuated to higher maintenance levels.
- Extent of dependency on nonorganic assistance: percent of maintenance (number of actions, MMH) at O level and I level performed by nonorganic personnel (broken down by Government civilians/contractor personnel/foreign nationals).
- Maintenance backlogs at O and I levels in terms of customary measures; include both awaiting maintenance and awaiting parts data.
- Turnaround times at O and I levels in terms of customary measures.
- Turnaround time of D-level component repairs (LRUs and SRUs).

b. Describe standards or goals for maintenance backlogs and turnaround times.

c. Provide assumptions and logic for computing SRU stockage at I level. Describe the tradeoffs between improving D-level repair turnaround time and increasing I-level SRU stockage for deployed squadrons.

6. Maintenance Flexibility (Sustainability)

All of the above data (Subsections 1 through 5) essentially pertain to peacetime operations. To help assess sustainability in wartime, empirical data on unit exercises and analytical data on simulated wartime conditions are required.

a. Describe the changes in maintenance workload and performance (as measured in terms of selected parameters in Subsections 2 through 5 above) during unit exercises. Provide data on extent of maintenance deferrals and duration (after the exercise) to catch up and return to "normal."

- b. Compare exercises with possible wartime scenarios in terms of preparation effort, maintenance concept, sortie rate, parts supply, and maintenance support capability.
- c. Discuss the extent (if any) to which war reserves spares kit (WRSK) (spare LRUs) and Avionics Intermediate Shop (AIS) shortfalls would limit wartime operating tempo of F-15 squadrons and provide the following information:
 - Percent of maintenance workload sustained in wartime
 - Alternative options to compensate for the maintenance deficiency
 - Actions programmed to eliminate maintenance resource shortfalls for current configuration combat squadrons
 - Actions taken or planned for the MSIP and F-15E programs that will make those squadrons more supportable in wartime.
- d. Describe the F-15's battle damage repair program and the extent to which wartime maintenance augmentation units are prepared to perform that mission (TOs, repair kits, special test equipment or maintenance aids, training, experience of personnel available, etc.).

7. Prime Equipment Reliability and Maintainability (R&M) Characteristics

- a. Provide the following system-level parameters and past trends:
 - Reliability as measured in terms of MTBF (mission critical), mean time between maintenance (MTBM) (all maintenance events), and MTBM (unscheduled maintenance)
 - Maintainability as measured in terms of mean time to repair (MTTR), differentiated between on-equipment and off-equipment at O level, and cumulative frequency distribution of repair time at O level
 - BIT performance as measured in terms of fault detection rate, fault isolation resolution, false alarm rate, and cannot duplicate (CND) rate.
- b. Provide maintenance workload data as a function of flying hour program as follows:
 - MMH per month at O level, divided into preventive and corrective maintenance, and into on- and off-equipment, for the average (specified) peacetime flying hour tempo.

- MMH per month at I level
 - MMH per month at D level attributable to F-15 maintenance (excluding overhaul)
 - Each of the above divided into F-15 prime equipment and support equipment
 - MMH/FH (O plus I level) and an estimate of the relationship between these two parameters.
- c. List the top 30 maintenance cost drivers in order of annual maintenance cost (repair frequency times cost per repair) and annotate each with its ranking in the top subsystems responsible for mission aborts.
 - d. Describe the major R&M-related product improvements that have been implemented, including the associated cost and results achieved. Provide the cumulate investment in those improvements and compare with the cumulative investment in other classes of product improvements, especially performance improvements.
 - e. Provide information on R&M-related product improvements programmed for the next 2 years and identify any remaining backlog in planned R&M improvements. Provide the details of the Tactical Air Force master plan for R&M actions that was scheduled to be published in March 1986.
 - f. Identify which of the maintenance cost drivers (identified in c. above) will be eliminated through the MSIP program.
 - g. Identify any voids in current plans to improve F-15 fault diagnostics (BIT and O level test sets) and possible approaches to correct those diagnostic shortfalls.

8. Manpower, Personnel, and Training

- a. Provide the following data on current manning:
 - Manning authorization by organization (Deputy Commander for Maintenance, aircraft generation squadron, equipment maintenance squadron, and component repair squadron), skill [Air Force Specialty Code (AFSC)], and skill level (3/5/7/9 or paygrade)
 - Average percentage fill, Air Force-wide

- Average experience level of each skill/skill level cohort
 - Personnel utilization by work center in peacetime versus war-time.
- b. Provide specific information on the F-15-related AFSC changes planned, schedule of implementation of those changes, and the benefits expected from those changes, including improvements in personnel utilization enabling manpower reductions.
 - c. Provide the following training information on F-15 maintenance related AFSCs:
 - Formal school duration
 - OJT duration (Field Training Detachment)
 - Availability and training effectiveness of maintenance training equipment
 - Extent of scheduled, supervised OJT in maintenance units
 - Certification process
 - Extent of job proficiency monitoring
 - Follow-on training available to career personnel
 - Specific plans or programs to upgrade maintenance training.

9. Repair Process Technology

- a. Describe the decision process used in determining the need for, or cost-effectiveness of, adopting new technology for F-15 maintenance and repair.
- b. Describe the sources and extent of information that is utilized by the F-15 System Manager to decide upon modernization of repair process technology.
- c. Provide an assessment of what new technologies would be cost-effective and specify the specific modernizations programmed or planned at this time, including the following areas:
 - Nondestructive inspection; or evaluation
 - Diagnostics
 - Paint removal and corrosion treatment
 - Cutting and welding

- Removal/installation of fasteners
 - Soldering/desoldering
 - Cable/connector repair
 - Composite repair.
- d. Nominate any candidate technologies for field-level maintenance productivity or quality improvements that are not currently programmed.

10. Maintenance Facilities and Equipment

- a. Provide the following data on the support and test equipment utilized in F-15 maintenance at the O level (especially test sets) and I level (especially the ATE at the AIS):
- Age and status of equipment
 - Failure rate, downtime, and support
 - Percent of I-level MMH expended on maintaining support equipment
 - Availability of equipment (i.e., including floats)
 - Adequacy of calibration services
 - Adequacy of power and air conditioning for environmentally sensitive equipment (ATE)
- b. Provide the following information on the performance of ATE and TPSs for diagnosing LRU failures:
- Diagnostic performance and runtime of each TPS used at the AIS
 - Average number of times an LRU must be processed by the same TPS until the LRU tests serviceable
 - Throughput capacity in terms of serviceable LRUs produced (3-shift operation)
 - Average turnaround time of LRU repairs
 - Reasons why the System Test Analysis Center (STAC) was not installed at Warner Robins Air Logistics Center (The STAC was deemed necessary in 1982 to resolve persistent diagnostic problems and inconsistencies in accordance with the requirements stated in the F-15 Computer Resources Integrated Support Plan.)

- c. Provide detailed information on the AIS upgrade program. Explain the steps taken to ensure that current AIS deficiencies will be eliminated or avoided.
- d. The F-15 operational concept has always relied on self-sufficiency when deployed. What options have been explored to reduce the airlift required as part of MSIP?
- e. Provide specific information on the modernizations planned or programmed for F-15 support equipment (other than the AIS upgrade under MSIP) and identify the associated funding programs (e.g., Asset Capitalization Program, Productivity Enhancing Capital Investments, etc.).

11. Technical Information and Maintenance Aids

- a. Provide the number and size (page count) of F-15 TOs and identify any electronic maintenance aids that are utilized by maintenance personnel. Describe their quality in terms of the following evaluation criteria:
 - Information retrievability (the ease with which needed information can be derived from maintenance documentation)
 - Accuracy (the correctness of the information presented by the maintenance documentation, including illustrations, part numbers, and procedural text)
 - Completeness (the extent to which all information needs can be satisfied by a given set of maintenance documentation)
 - Reliability (the availability of the presentation medium (i.e., printed manuals, microfiche or microfilm readers/printers, electronics maintenance aids) to the technician at the time it is needed)
 - Illustration adequacy (the extent to which needed illustrations are absent)
 - Grouping of information (the extent to which information required to perform a maintenance task is located close together instead of being dispersed)
 - Format standardization (the similarity in format among all TOs supporting tactical aircraft in the Air Force). For example, to what extent has the Air Force standardized its troubleshooting TOs in the Functionally Oriented Maintenance manuals format (MIL-M-24100).

- Ambiguity (the probability that an item of information may be misconstrued)
 - Clarity of illustrations (the extent to which given illustrations match an accepted checklist of "good" features associated with comprehensibility of graphic information)
 - Portability (the ease by which the presentation medium, printed manual or electronic aid, can be worked with at the work site)
 - Ease of revision (the expediency and cost of the process by which the need for revisions is identified and the revisions are made and disseminated)
 - Readability (the difficulty of understanding the maintenance documentation, stated in terms of the level of education required for reading comprehension).
- b. To the extent the above checklist identifies serious shortcomings in F-15 TOs, provide information on any improvements programmed or planned.
 - c. The Air Force has developed and evaluated the Automated Technical Order System (ATOS) as an user-interactive electronic maintenance aid in lieu of the printed medium. Describe the impediments to implementing ATOS and provide information on any specific plans for ATOS implementation in support of F-15 maintenance.
 - d. The Integrated Maintenance Information System (IMIS) is a long-term R&D program for processing, integrating, and displaying maintenance information, using various computer-based systems, with the first application planned for the Advanced Tactical Fighter. IMIS, therefore, has little to offer for F-15 maintenance within the next 10 years. Identify any shorter range projects in the technical information area that could materially contribute to improving F-15 maintenance performance at O and I levels.

12. Management Systems

- a. Identify and describe the various types of management, decision support, and control systems that are available to or are being evaluated to support squadron maintenance managers; including the following:
 - Work scheduling
 - Automatic retrieval of maintenance history of specific items

- Serial number tracking
 - Management decision tools
 - Data entry automation for maintenance data collection.
- b. Describe any additional computer applications (enhancements to existing systems or new systems) that could contribute to improved maintenance performance, productivity, and efficiency.

13. Comments and Critique

- a. Estimate the extra effort (man-days) expended in responding to this list
- b. Critique any requested data that are deemed impractical or not meaningful
- c. Suggest alternative measures of maintenance performance
- d. Identify the set of maintenance parameters that the Air Force commonly monitors and comment on the adequacy of that set for the purposes of assessing maintenance performance.

14. Candidate Projects

- a. Provide a list of identified projects that would reduce maintenance costs but are not programmed within the next 2 years. Categorize those projects by maintenance area as follows:
- Product improvements (R&M related improvements)
 - Manpower/Personnel/Training
 - Maintenance facilities and equipment
 - Repair process technology
 - Technical information/maintenance aids
 - Management and control systems.
- b. For each of the above projects, provide the estimated return on investment (including definition of how arrived at) and explain why the project has not been programmed under one of the existing programs (e.g., Product Improvement Program, Productivity Enhancing Capital Investment Program, Asset Capitalization Program, Value Engineering, etc).

- c. Identify other maintenance-related projects that are currently under consideration or in a proposal stage.
- d. Provide recommended priorities for maintenance improvement projects, including those to eliminate potential "war stoppers" and reduce maintenance costs.

FOLLOW-UP

The proposed maintenance review of fielded weapons systems is designed to identify opportunities for maintenance improvements through investments in better field maintenance facilities and equipment, more advanced repair process technology, better management tools and support systems, improved technical information or maintenance aids, better utilization and training of maintenance personnel, and/or prime equipment maintainability improvements. The maintenance review process, therefore, does not stop with the response to the above list. After the data have been reviewed, the System Manager should prepare a detailed Maintenance Improvement Proposal for the development, demonstration, and implementation of any needed improvements, including cost and schedule.

APPENDIX C

CURRENT PROGRAMS TO REDUCE WEAPONS SYSTEMS COSTS

This appendix describes DoD programs aimed at reducing weapons system acquisition and support costs through productivity enhancements, exploitation of advances in production and repair technologies, and improvements in equipment reliability and maintainability. The primary purpose of this review is to identify technical aspects of weapons system maintenance not adequately addressed by current programs. A secondary purpose is to identify strengths and weaknesses of existing programs including how they are administered.

For each program, this appendix provides information about the objectives, charter, funding level (as of April 1986), focus, management, project selection criteria, and automated data bases. For programs managed by the Office of the Secretary of Defense (OSD), the descriptions begin with general characteristics and the OSD portion of the program, followed by separate descriptions for each of the Military Services.

MANUFACTURING TECHNOLOGY PROGRAM

Objective

The objective of the Manufacturing Technology (ManTech) Program is to improve the productivity and responsiveness of the industrial base by advancing manufacturing technology and stimulating industrial modernization through cost and risk reduction.

Charter

The ManTech Program is authorized by Department of Defense Instruction (DoDI) 4200.15, "Manufacturing Technology Program," 24 May 1985.

Funding

Until recently, the ManTech Program had been funded from the procurement appropriation. Since FY84 (1983 for Army), however, Congress has mandated that

the program be funded from the Research, Development, Test, and Evaluation (RDT&E) appropriation. This funding is shown by DoD Component in Table C-1.

TABLE C-1
MANTECH FUNDING
(\$Millions)

DoD Component	Fiscal Year		
	1985	1986	1987
Army	80	76	24
Navy	50	52	34
Air Force	56	65	85
Defense Logistics Agency	3	5	11
TOTAL	189	198	154

That table shows that ManTech is a large program (nearly \$200 million in 1986) and that the Air Force share has been steadily increasing while the Army and Navy shares have been decreasing.

Focus

The focus of the ManTech Program is on the development of improved manufacturing processes, techniques, and equipment, based on proven concepts with broad applications for defense material. The ManTech Program supports projects in six technical areas. Those areas, and the relative emphasis they receive, are shown in Table C-2.

Management

Policy and coordination responsibilities for the ManTech Program rest with the Industrial Resources Directorate, Office of the Deputy Assistant Secretary of Defense (Production Support), Assistant Secretary of Defense (Acquisition and Logistics). Program management is mainly performed by the Military Services — they develop the 5-year plans and evaluate and follow-up on individual ManTech projects. ManTech Advisory Group subcommittees provide assistance by reviewing projects to avoid duplication of effort, identifying areas of common interest for

TABLE C-2
TECHNICAL EMPHASIS OF MANTECH

Technical Area	Percent of FY84 Funding
Electronics and Optics	29
Computer-Aided Manufacturing	20
Inspection and Test	18
Metals	15
Ammunition	9
Nonmetals	9
TOTAL	100

possible multi-Service funded projects, and enhancing technology transfer among the Military Services.

Criteria

ManTech projects must meet the following selection criteria:

- A well-defined DoD requirement for the technology must exist.
- The technology must be deliverable in time to meet the requirement.
- The anticipated results must be applicable to more than one end item.
- A specific implementation plan must exist.
- The potential must exist for multi-Service sponsorship.

Projects that typically are not supported by ManTech are those that stress applications of existing technology; purchases of off-the-shelf equipment (unless they are part of a first-case project demonstration); or, investments more appropriately funded by other sources (such as design changes).

Data Base

Each Military Service has a ManTech management information system in various stages of development or implementation. The DoD also has established a defense-wide data base at the ManTech Information Analysis Center (MTIAC).

INDUSTRIAL MODERNIZATION INCENTIVES PROGRAM

Objective

The objective of the Industrial Modernization Incentives Program (IMIP) is to encourage increased capital investment by defense industry in order to reduce weapons system, subsystem, and component acquisition costs and to accelerate the implementation of modern equipment and management techniques in the industrial base.

Charter

The IMIP was formally established by DoD Directive (DoDD) 5000.44, "Industrial Modernization Incentives Program (IMIP)," August 1985, which prescribes policy and assigns responsibilities. Detailed criteria, procedures, and guidance for program implementation are contained in DoD Guide 5000.44-G, "IMIP," August 1985 (Draft). Acquisition regulations are provided by DoD Federal Acquisition Regulation (FAR) Supplement Section 15.872, "Industrial Modernization Incentives."

Funding

Only contractor funds are used for actual capital investments. DoD funds (from program/weapons system and industrial preparedness program elements) as well as contractor funds are used for factory analyses and applications engineering studies. DoD funds for studies and analyses can be provided directly or indirectly. Indirect funding means that allowable expenses are charges to overhead or other accounts in production programs or have the expenses offset through incentive payments.

Each Military Service has taken a different approach to IMIP. The Air Force has used IMIP funds to foster implementation of demonstrated technologies that require considerable engineering and software development. From FY78 through FY84, the Air Force provided contractors with an average of approximately

\$37 million per year in direct funding for IMIP. In FY85, the Air Force budgeted \$40.6 million for IMIP.

Compared with that of the Air Force, the Navy and Army IMIP efforts are smaller, more recent, and primarily involve large contractors. The Navy has not provided direct funding for IMIP but has allowed indirect funding since FY83. For FY87, the Navy is seeking \$2 million to provide direct funding for factory analysis efforts for several small businesses. Other Navy contractors can still participate in Navy IMIP efforts through indirect funding to recover costs incurred. The Army's involvement in IMIP has varied. When it initially participated in the program, it provided \$7 million of direct funding in FY81; this funding decreased to \$1.4 million in FY85 and is being increased through an Army request for a \$5.9 million IMIP budget for FY86.

Focus

The IMIP process is aimed at achieving between a Military Service and a contractor a negotiated business agreement that will result in actions to modernize plant or product line so that productivity and quality is increased, lead-times and cost are reduced, and surge capability is improved.

The IMIP process involves three phases:

- Phase I: Factory or product line analysis
- Phase II: Applications engineering
- Phase III: Contractor capital investment and implementation.

Phase I is a top-down study of the contractor's factory operation. The study results in a modernization plan for the entire facility or a single product line. The plan identifies investments that will result in cost reductions but not enough to give the contractor an adequate return on investment. DoD may directly fund the Phase I analysis. Phase II consists of the design and development of a new manufacturing system, which may include new technology or equipment tailored to specific production applications. Phase II results in a capital investment proposal from the contractor. In that phase, DoD funds may be used to develop the technology but not to purchase the capital equipment. During Phase III, the contractor acquires the capital equipment and software for installation and operation, while the DoD

weapons system program office pays incentives to the contractor in accordance with the negotiated prior agreements.

In contrast to the Navy and Army, the Air Force currently has several IMIP efforts ongoing in all three phases, as shown in Table C-3. The projected cost reductions of those projects are also shown in that table.

TABLE C-3
DoD IMIP PROJECTS
(\$ Millions)

DoD Component	Active Projects/Estimated Cost Reduction		
	Phase I	Phase II	Phase III
Air Force	12/\$199	16/\$2,657	5/\$1,383
Navy	9/\$862	5/\$745	—
Army	3/\$831	—	—
TOTAL	24/\$1,892	21/\$3,402	5/\$1,383

Management

Policy guidance for IMIP is provided by the Industrial Productivity and Quality Assurance Directorate, Office of the Deputy Assistant Secretary of Defense (Production Support), Assistant Secretary of Defense (Acquisition and Logistics). Primary responsibility for program execution rests with weapons system program managers in the Military Services.

Criteria

Generally, IMIP eligibility depends upon two sets of circumstances: (1) competitive market forces are inadequate to motivate contractors to modernize and (2) significant benefits (i.e., cost savings, reduced lead times, improved product quality and reliability, enhanced surge capability, etc.) would accrue to the Government from such modernization.

Several factors are considered in the selection of IMIP proposals:

- Incentive for contractor capital investments which goes beyond the minimum required
- Return-on-investment
- "Fit" of the IMIP proposal in the overall acquisition strategy
- Interaction with other incentives
- Negotiated Productivity Savings Reward.

Data Base

Currently, the DoD does not have an automated data base used to manage the IMIP Program; plans for such capability are underway, however. The Air Force, in 1985, installed an IMIP information system for its own internal use.

VALUE ENGINEERING PROGRAM

Objective

The objective of the Value Engineering (VE) Program is to promote VE actions to reduce costs and improve productivity of DoD in-house and contractor resources.

Value engineering is defined as an analytic discipline used for analyzing or redesigning a product or process to achieve essential functions at minimum life cycle cost consistent with required performance, reliability, maintainability, interchangeability, quality, and safety.

Charter

The VE Program is authorized by DoDD 4245.8, "DoD Value Engineering Program," 7 May 1984.

Funding

The FY85 funding for the VE Program is shown in Table C-4.

Focus

The VE Program has two segments: one for contractors and another for in-house. Both segments may reflect value engineering improvements in products or

TABLE C-4
VALUE ENGINEERING FUNDING
(FY85)

DoD Component	Amount (\$ Millions)
Army	13.3
Navy	23.5
Air Force	31.7
TOTAL	68.5

processes. Most contractor VE change proposals are for product changes (i.e., manufacturing cost reduction) for weapons systems in full-scale development, production, and postproduction. In-house VE actions, on the other hand, are split evenly between product and process changes.

Management

The Under Secretary of Defense for Research and Engineering (USDRE) is responsible for providing overall policy guidance and program oversight. Each DoD Component is responsible for managing its own VE Program.

A DoD VE Committee, composed of senior representatives from DoD Components and chaired by a representative from the Office of the Deputy Under Secretary of Defense for Research and Engineering (Acquisition Management), reviews progress and problems and recommends policy changes.

Criteria

No specific criteria are available to determine the applicability of the principles of VE since virtually every product or process is susceptible to improvements or cost cutting. In recent years, the main thrust of the VE Program has been aimed at acquisition cost reduction. To this end, the DoD established a savings goal to be achieved by the Military Services through the adoption of VE change proposals submitted by contractors. The goal was set at 0.7 percent of the total procurement obligational authority for each Military Service.

Data Base

In FY85, a 2-year pilot program was initiated for a VE Data Information Storage and Retrieval System (VEDISARS). It contains information on implemented contractor VE change proposals and is accessible to all DoD Components and private industry contractors via the Government-Industry Data Exchange Program.

ASSET CAPITALIZATION PROGRAM

Objective

The objective of the Asset Capitalization Program (ACP) is to increase the efficiency and enhance the productivity of industrial fund activities through capital investments.

Charter

The ACP was inaugurated by memorandum from the Deputy Secretary of Defense on 19 August 1981. Amplifying implementation instructions were provided by an Assistant Secretary of Defense (Comptroller) [ASD(C)] memorandum on 14 January 1982.

Funding

The ACP provides funding for two types of industrial fund activities: industrial and commercial. The industrial type activities include Army depots and arsenals; Naval shipyards, air rework facilities, and ordnance facilities; and Air Force air logistics centers. The commercial type activities include the Military Traffic Management Command, Military Sealift Command, Naval public works centers and aeronautical engineering centers, and various laboratories.

Each of the Military Services and a few Defense Agencies participate in the ACP. The extent of that participation is shown in Table C-5 which presents recent and planned funding levels. The table shows ACP funding is dominated by the Navy, which, in FY87, will have more than two-thirds of the total.

Focus

ACP funds are used for investments in capital equipment, minor construction, management information systems, and alteration and rehabilitation of assets.

TABLE C-5
ACP FUNDING
(\$Millions)

DoD Component	Funding		
	FY85	FY86	FY87
Army	146.7	151.1	104.0
Navy	602.7	681.1	757.5
Marine Corps	4.3	5.0	9.1
Air Force	167.0	193.1	147.9
Defense Agencies	3.0	1.2	39.5
TOTAL	923.7	1,031.5	1,058.0

Table C-6 shows the emphasis on each type of investment. Most ACP investments are for capital equipment, as the table indicates. Not shown in the table is the distribution of capital equipment investments between industrial and commercial type activities. Sixty-nine percent of ACP equipment funds are assigned to industrial type activities.

TABLE C-6
ACP INVESTMENTS
(\$Millions)

Type of Investment	Funding		
	FY85	FY86	FY87
Capital equipment	804.6	856.7	907.1
Minor construction	47.5	77.4	70.6
MIS	54.1	71.2	64.3
Asset alteration	17.6	26.2	16.0
TOTAL	923.7	1,031.5	1,058.0

A special application of the Air Force's ACP is Maintenance Sponsored Technology (MST). The objective of MST is to expeditiously introduce state-of-the-art equipment into the depot maintenance industrial complex. A description of MST is presented in a subsequent section of this appendix dealing with Service Unique Programs.

Management

Guidance for the ACP is provided by the ASD(C), while program administration is accomplished by the individual DoD Component industrial fund managers.

Criteria

Capital investments by industrial fund activities must be financed through depreciation expenses and ACP surcharges included in the industrial fund rates charged to customers.

Data Base

No automated data base is used to manage the ACP program.

PRODUCTIVITY ENHANCING CAPITAL INVESTMENT PROGRAM

General

Objectives

The three objectives of the Productivity Enhancing Capital Investment (PECI) Program are to:

- Improve the efficiency and effectiveness of defense organizations and activities by encouraging the application of capital equipment and facilities to improve methods of operation
- Increase the level of consciousness among defense managers of the potential for productivity improvement through capital investments
- Promote the substitution of capital for labor as a means for optimizing the output of the defense work force.

Charter

DoDI 5010.36, "Productivity Enhancing Capital Investment," 31 December 1980, establishes policy for the DoD PEGI Program.

Funding

The DoD has had a formal productivity program since 1975, growing from small origins into what is now called the PEGI Program. Investment efforts began in FY77 with off-the-shelf, low-cost equipment, which returned costs within 2 years. In FY81, the program was expanded to include major equipment and facilities with larger project costs and longer payback periods. In the same year, other Military Service/DoD Agency investment funds were established to encourage complementary investments from DoD Component budgets. The DoD PEGI Program is now divided into three major funds:

- Productivity Enhancing Incentive Fund (PEIF) for equipment projects costing less than \$100,000 and returning costs within 2 years. This program is funded and managed by each DoD Component.
- Productivity Investment Fund (PIF) for major equipment and facility projects costing more than \$100,000 and returning costs within 4 years after becoming operational. The funding and management of this program, including individual project selection, is controlled by OSD.
- Component Sponsored Investment (CSI) for mission-oriented projects that complement OSD funds but have payback periods and cost criteria individually determined by each Military Service or DoD Agency. This program is funded and managed by each DoD Component.

The FY86 budget for the PEGI Program totaled \$197 million, distributed among the three funds. This distribution and the recent program funding history are displayed in Table C-7. PIF is the largest of the three programs, ranging between two-thirds and three-fourths of total PEGI funds with the FY86 PIF at 70 percent of total. The budget planned for the FY87 PEGI Program represents a 30 percent increase over the previous year.

The Military Services and DoD Agencies provide the funds for the PEIF Program. Those funds are set aside in advance to enable ready financing and quick project implementation. OSD establishes the PIF Program funding levels in the Five Year Defense Plan; the PIF funds are also set aside in advance. The Military Services and DoD Agencies establish the funding levels of the CSI Program in the

TABLE C-7
PECI FUNDING HISTORY
(\$ Millions)

PECI Fund	Funding					
	FY82	FY83	FY84	FY85	FY86	FY87
PEIF	8.8	28.8	31.6	—	47.8	35.0
PIF	90.0	120.9	128.6	136.4	138.5	176.2
CSI	17.4	26.7	30.0	—	10.8	46.0
TOTAL	116.2	176.4	190.2	—	197.1	257.2

normal Planning, Programming, and Budgeting System process. CSI projects are identified on specific budget lines in each of the various appropriations.

Focus

The focus of each of the three funds used in the PECI Program is described in subsequent subsections of this appendix.

Management

The Defense Productivity Program Office (DPPO) which reports to the Requirements and Analysis Directorate, Deputy Assistant Secretary of Defense (Resource Management and Support), ASD (Force Management and Personnel), provides policy guidance, monitors overall implementation of the PECI Program, and also manages the funds and selects projects for the PIF program. The Military Services and DoD Agencies perform the funds management and project selection for PEIF and CSI.

Productivity reports and a summary of audit results are provided annually by each Military Service and DoD Agency to DPPO. These reports require specific PEIF and PIF investment information as a part of the reporting requirement. The reporting of CSI data is encouraged but not required. In addition, each DoD Component maintains detailed funding, investment, savings, and audit information on PIF projects and programs and summary information on PEIF projects.

Criteria

PECI project selection and management differs for each of the three program funds. PEIF and OSD-sponsored PIF projects are selected using criteria established by OSD. However, PEIF projects are selected by the DoD Components while PIF projects are competitively selected by OSD from candidate proposals submitted by the DoD Components. CSI projects are sponsored, selected, and managed by the DoD Components.

OSD-sponsored PEFI projects must meet certain criteria to be eligible for funding consideration. Projects financed from PEIF are limited to:

- Investments costing less than \$100,00 (or limits established in annual appropriations) that are expected to return all investment costs within 2 years of the operational date
- Off-the-shelf, commercial equipment
- Those not included in other funding requests or denied by Congress in prior years
- Those justified on the basis of the potential productivity improvement quantified as tangible saving (personnel or material) realized through changes in operating methods, processes, or procedures.

Projects financed from PIF are approved by OSD for inclusion in DoD Component budgets and limited to:

- Investments costing at least \$100,000 that are expected to return all investment costs (acquisition, transportation, and installation) within 4 years of the operational date through savings measured in budget year dollars
- Functions currently measured under the DoD Productivity Program or planned to be measured and included in DoD Component productivity reports
- Those not directed toward acquisition and ownership of equipment and facilities currently being leased
- Those not establishing an in-house capability for operations readily and more economically available from commercial sources.

Terminology

PEIF and CSI funds in the PEFI Program each have a different name in the Military Services. The PEIF is called Quick Return on Investment Program (QRIP)

in the Army, PEIF in the Navy, and Fast Payback Capital Investment Program (FASCAP) in the Air Force. The CSI is called Productivity Enhancing Capital Investment Program (PECIP) in the Army, Cost of Ownership Reduction Investments (COORI) in the Navy, and Component Sponsored Investment Program (CSIP) in the Air Force. Each of these programs is described below beginning with the centrally managed OSD-PIF program.

OSD-PIF

Objective

The objective of the PIF program is as stated previously in this appendix.

Charter

DoDI 5010.36, as cited earlier.

Funding

The PIF program funding profile is provided in Table C-7. It shows \$176.2 million for PIF in FY87, nearly double the funding level of FY82.

The distribution of PIF monies among the DoD Components in FY85 is shown in Table C-8, which also shows the different appropriations used to fund PIF projects. In FY85, the Army and Air Force together accounted for 70 percent of the PIF program funds. The distribution among appropriations shows that procurement accounts received nearly half of PIF funding; military construction accounted for another quarter.

Focus

The PIF program covers the following major functions: communications, comptroller, logistics, manufacturing, medical, personnel, security, services, and other (e.g., management and administration). The logistics function includes real property maintenance, equipment maintenance, procurement, supply, and transportation.

Several PIF projects involve, or have potential application to, equipment maintenance functions and subfunctions. During the period FY82 through FY86, the PIF program funded 276 projects. The number of projects by function is shown in

TABLE C-8
DISTRIBUTION OF FY85 PIF
(\$ Millions)

Appropriation	Army	Navy	Marine Corps	Air Force	Defense Agencies	Total	Percent of Total
Procurement	28.4	10.3	8.6	3.3	10.9	61.5	45
Construction	3.9	—	—	29.3	—	33.2	24
Operations and Maintenance	11.4	7.5	0.2	7.9	1.8	28.8	21
Research and Development	6.8	2.0	—	4.2	—	13.0	10
TOTAL	50.5	19.8	8.8	44.7	12.7	136.5	100

Table C-9. Projects directly involving equipment maintenance represent a small fraction of the total. Projects involving production and manufacturing are shown separately because of their potential application to equipment maintenance.

TABLE C-9
MAINTENANCE EMPHASIS OF PIF PROJECTS
(FY82 - FY86)

Function	Number of Projects	Percent of Total
Depot Maintenance	24	8
Intermediate Maintenance	12	4
Production and Manufacturing	76	28
Other	164	60
TOTAL	276	100

The distribution of PIF investments among functions is similar to the distribution of specific projects among functions. The PIF investment history by function is displayed in Table C-10. The 5-year totals indicate that 15 percent of PIF investments directly involve equipment maintenance, although some portion of Production and Manufacturing may also be relevant to the maintenance function.

TABLE C-10
PIF INVESTMENT HISTORY BY FUNCTION
(\$ Millions)

Function	Fiscal Year					Total	Percent of Total
	1982	1983	1984	1985	1986		
Depot Maintenance (Ships)	8.6	2.0	4.1	—	—	14.7	2
Depot Maintenance (Other)	11.2	1.0	—	15.9	34.5	62.6	11
Intermediate Maintenance	—	0.5	2.4	0.7	0.3	3.9	1
Motor Vehicle Maintenance	0.1	—	—	3.9	—	4.0	1
Production and Manufacturing	14.8	17.9	6.9	16.3	34.5	90.4	15
LOGMARS	—	67.3	—	8.1	—	75.4	13
Other	56.7	113.3	64.2	45.7	60.7	340.6	57
TOTAL	91.4	202.0	77.6	90.6	130.0	591.6	100

Management

The DPPO manages the PIF program. It establishes policy, manages funds, selects projects, and retains project oversight authority. Project oversight is performed primarily through the use of the annual productivity reports submitted by the DoD Components. It is augmented by field visits, but they have been generally limited to visits to unusually promising project sites or sites with projects experiencing unusual difficulties. Specific project monitoring remains the responsibility of the individual DoD Component and is usually delegated to the major command level or below.

Criteria

In addition to the project eligibility criteria stated earlier, recent practice indicates other exclusions. Projects involving investments in equipment for industrially funded activities are excluded; those projects, however, are within the purview of the PEGI Program. Investments in government-owned, contractor-operated (GOCO) facilities are also generally precluded, but, Army Ammunition Plants, a special category of GOCO facilities, are included. In recent years, however, the practice has been to treat candidate projects for GOCO facilities on a case-by-case basis, with the

guiding principle being to exclude investments in GOCO facilities in which contractors profit from the manufacture and sale of products from the facility to the U.S. Government.

Criteria for project selection for PIF financing give top priority to investments that are amortized in the shortest period of time and with the highest potential internal rate of return on investment or highest net present value. Projects with identical return rates or net present values are then ranked according to those that:

- Save whole personnel authorizations that can be reapplied locally
- Save whole personnel authorizations that can be reallocated elsewhere
- Avoid overtime costs
- Reduce materiel consumption
- Produce other cost savings.

Data Base

Information on the PIF program is maintained in an automated form capable of operation on IBM personal computers. The data base includes four interrelated files: PIF projects, appropriations, cost/benefit information, and point-of-contact/address files. Currently only preinvestment data are maintained for PIF projects.

Army Quick Return on Investment Program (QRIP)

Objective

The objective of the Army QRIP (a PEIF program) is to increase productivity, reduce costs, save manpower, and improve readiness through the application of modern equipment and facilities.

Charter

The establishment of the QRIP is promulgated in Army Regulation 5-4, "Department of the Army Productivity Improvement Program," 18 August 1976 with Change 1 dated 1 August 1982. This regulation assigns responsibilities and provides policies, procedures, and reporting instructions for the Department of the Army Productivity Improvement Program.

Funding

The funding profile for the QRIP is shown in Table C-11. The appropriation used is predominantly Other Procurement, Army, although approximately 13 percent of the funding is Operations and Maintenance, Army to cover installation costs.

TABLE C-11
QRIP FUNDING BY FISCAL YEAR
(\$ Millions)

Fiscal Year				
1985	1986	1987	1988	1989
15.5	14.5	54.5	36.5	44.7

Focus

Most QRIP projects are aimed at productivity improvements in office automation and administrative functions. Field maintenance receives little emphasis. This is demonstrated by the tabulation of projects taken from the U.S. Army Forces Command (FORSCOM) program for FY85 and shown in Table C-12.

Management

QRIP policy and program oversight is the responsibility of the Comptroller of the Army (DACA-PMP). Project approval and administration is delegated to the major command level.

Criteria

Project eligibility criteria were stated previously in this appendix. Project selection for funding and implementation is based on a composite of three separate rankings of internal rate of return, savings-to-investment ratio, and rate of investment per manpower space. For closely ranked projects, special consideration is given for readiness improvements and manpower savings.

TABLE C-12
EMPHASIS OF FORSCOM QRIP PROJECTS
(FY85)

Function	Projects	
	Number	Percent
Office Automation/Administration	165	76
Facility Support	29	13
Field Maintenance	9	4
Other	15	7
TOTAL	218	100

Data Base

No automated data base is used to manage the QRIP.

Army Productivity Enhancing Capital Investment Program (PECIP)

Objective

The objective of the Army PECIP (a CSI program) is the same as that stated for the QRIP.

Charter

Same as that of QRIP.

Funding

A funding profile for the Army PECIP is displayed in Table C-13. The appropriation used is predominately Other Procurement, Army.

Focus

In FY85, FORSCOM had five PECIP projects: three for facility support and two for office automation.

TABLE C-13
PECIP FUNDING BY FISCAL YEAR
(\$ Millions)

Fiscal Year				
1985	1986	1987	1988	1989
6.7	6.2	23.2	15.6	19.1

Management

PECIP management responsibilities are the same as for QRIP.

Criteria

Eligibility criteria for PECIP projects are the same as those for OSD PIF projects. PECIP projects are selected for funding and implementation based on the same ranking methodology used for QRIP, but first priority goes to those projects eligible for the OSD PIF Program but unfunded by OSD.

Data Base

There is no automated data base used for managing the PECIP.

Navy Productivity Enhancing Incentive Fund (PEIF)

Objective

The objective of the Navy PEIF is threefold: to advance the efficiency and effectiveness of activities by encouraging the application of capital equipment to improve methods of operation; to increase the consciousness of Navy managers of the potential for productivity improvement through capital investments; and to promote the substitution of capital equipment for labor to optimize the output of the work force.

Charter

Policy and procedures for the Navy's PEIF are contained in Navy Comptroller Instruction (NAVCOMPTINST) 7000.38A, "Productivity Enhancing Incentive Fund

(PEIF)/The Productivity Enhancement Capital Investment Fast Payback Program," 30 December 1982.

Funding

The Navy funds its PEIF program using the Other Procurement, Navy appropriation. This applies whether the projects are for Navy or Marine Corps activities. PEIF funds are set aside in advance to provide ready financing and quick project implementation. Table C-14 shows recent and planned levels of Navy funding for PEIF.

TABLE C-14
NAVY PEIF FUNDING HISTORY

(\$ Millions)

Fiscal Year				
1984	1985	1986	1987	1988
3	3	1	3	9

Focus

Recent Navy PEIF projects have tended to focus on maintenance, training, and data automation, as shown in Table C-15. Projects supporting field maintenance account for more than 50 percent of PEIF projects. They are found mostly at Shore Intermediate Maintenance Activities and Aircraft Intermediate Maintenance Departments. Many of those projects, however, are small investments – they totaled only \$567,900.

Although the Navy's PEIF funding levels are modest, generally an insufficient number of projects are approved to fully use the funds that have been set aside. This condition has held true for every year except FY85 when the funding limit was reached primarily because of a surge in projects involving office automation equipment.

TABLE C-15

MAINTENANCE EMPHASIS OF NAVY PEIF PROJECTS

(Selected Projects - FY84)

Function	Number of Projects	Percent of Total
Field Maintenance	24	56
Data Automation	5	12
Training	4	9
Other	10	23
TOTAL	43	100

Management

NAVCOMPT has fiscal responsibility for the Navy's PEIF program. The Chief of Naval Operations (CNO) reviews proposals submitted by Navy activities to validate the requirement and verify the proposal's technical soundness. [The Commandant of the Marine Corps conducts technical screening for Marine Corps activities.] Once proposals are validated, CNO acts as the financial administrator for NAVCOMPT to verify proposed payback computations and fund allocations. Funded projects are reviewed continuously by the CNO to assure financial control of the PEIF program. Certain proposals receive additional technical reviews prior to submission to CNO.

Criteria

To be eligible for PEIF funding, candidate project investment costs must not exceed \$100,000 and the project must amortize the investment within 2 years of its operational date. Project selection for PEIF financing gives top priority to investments that amortize the investment in the shortest period of time with the highest dollar benefit. In addition, the approval process emphasizes consistency with Navy long-range planning and programming objectives and applicability to assigned missions and workloads. Projects not requiring industrial plant equipment and costing less than \$25,000 may be initiated and financed at the local level without CNO and NAVCOMPT approval. These projects may be subsequently reimbursed

by NAVCOMPT upon receipt of project documentation and depending upon the availability of funds.

Data Base

The Navy does not use an automated data base to manage its PEIF.

Navy Cost of Ownership Reduction Investments (COORI)

The Navy has funded this CSI-type program in only 2 years: FY82 and FY83. As a result of recent inactivity, the program is not described here.

Air Force Fast Payback Capital Investment Program (FASCAP)

Objective

The objectives of the Air Force FASCAP (a PEIF-type program) are twofold: to reduce the cost of goods and services and to reduce the cost to maintain the required level of effectiveness or to increase the level of effectiveness within existing or reduced cost.

Charter

The establishment of FASCAP is promulgated in Air Force Regulation 25-3, "Air Force Productivity Enhancement Program," 25 February 1982, with Changes 1 and 2, the latter dated 7 September 1983. This regulation covers all existing Air Force productivity-related programs and provides a framework for focusing and coordinating these programs to reach a common objective — improved productivity. This regulation also covers the policies, procedures, responsibilities, and reporting instructions of the Air Force Productivity Enhancement Program.

Funding

The funding for FASCAP comes predominantly from the Other Procurement, Air Force appropriation. In FY86, it amounted to approximately \$10.5 million. Additional equipment installation funds come from the Operations and Maintenance, Air Force appropriation.

Focus

Most FASCAP projects are aimed at productivity improvements in office automation and administration functions. Field maintenance receives little emphasis. This is shown in Table C-16, which contains a tabulation of Air Force FASCAP projects for FY85 by function.

TABLE C-16
EMPHASIS OF AIR FORCE FASCAP
(FY85)

Function	Projects	
	Number	Percent
Office Automation/Administration	113	58
Medical	51	26
Facility Support	10	5
Field Maintenance	9	4
Other	13	7
TOTAL	196	100

Management

FASCAP policy and oversight is the responsibility of the Director of Manpower and Organization, Headquarters, U.S. Air Force (AF/MPMZ). Project approval and administration is delegated to the Air Force Management Engineering Agency.

Criteria

Project eligibility and selection criteria are as stated previously, except that the Air Force excludes investments of less than \$3,000. (Those investments are more appropriately funded from the Operations and Maintenance, Air Force appropriation.)

Data Base

An automated data base is not used for managing the Air Force FASCAP.

Air Force Component Sponsored Investment Program (CSIP)

Objective

The objective of the Air Force CSIP is the same as that for FASCAP.

Charter

The charter for the CSIP is the same as that for FASCAP.

Funding

The funding for CSIP comes predominantly from the Other Procurement, Air Force appropriation. In FY86, it amounted to approximately \$1.2 million.

Focus

In FY86, the Air Force had four CSIP projects: two training simulators, one automated message processing project, and one office information system project.

Management

CSIP policy and oversight is the responsibility of the Director of Manpower and Organization, Headquarters, U.S. Air Force (AF/MPMZ). CSIP project priorities are assigned by the Air Staff Productivity Committee and project approval is given by the Assistant Secretary of the Air Force for Financial Management.

Criteria

Eligibility criteria for CSIP projects are the same as those for OSD PIF projects. Selection of CSIP projects for funding and implementation is given first to those projects eligible for the OSD PIF Program but not funded. The payback period for Air Force CSIP projects can be extended to 5 years if otherwise eligible for Air Force funding.

Data Base

An automated data base is not used for managing the Air Force CSIP.

PRODUCT IMPROVEMENT PROGRAMS

The purpose of product improvement programs is to modify existing weapons systems and equipment, including their subsystems and components, in order to

improve performance, operational capability, reliability and maintainability, safety, production or operating and support costs, or other factors.

Each Military Service has established product improvement programs, but there is no OSD functional office focal point for them. The Army and Air Force each have singular programs, while the Navy has separate programs for ships, aircraft (including those operated by the Marine Corps), and Marine Corps ground equipment. This section describes the Army and Air Force programs and the Navy's aircraft program.

Army Product Improvement Program

Objective

The objective of the Army Product Improvement Program is to extend the useful life of existing equipment rather than develop new equipment. The program provides the means for reconfiguring several types of equipment to:

- Increase personnel safety or reduce equipment damage
- Improve operational capability
- Reduce production costs or operating and support costs
- Improve reliability, availability, or maintainability
- Correct performance deficiencies
- Improve rationalization, standardization, and interoperability and compatibility
- Comply with regulatory requirements
- Conserve energy
- Conform to Manpower and Personnel Integration human factors initiatives.

Charter

The Army's Product Improvement Program is authorized and managed in accordance with Army Regulation 70-15, "Product Improvement of Materiel," 15 July 1980 and Army Materiel Command Letter of Instruction, "Conduct of the Product Improvement Program," UAMCDE-PIP, 20 December 1984.

Funding

The Army's total funding requirement for product improvement proposals (PIPs) is nearly \$34 billion. The funding covers all three phases of the PIP cycle: Phase I—Engineering and Prototype Development; Phase II—Procurement of Modification Kits; and Phase III—Kit Application. Currently, Army PIPs are funded at \$1.8 billion to \$2.0 billion per year. That funding covers 70 to 75 percent of approved PIP annual requirements but is down from past years when 90 percent were funded. Recent funding has come from three different appropriations — Procurement (75 percent); Operations and Maintenance (20 percent); and Research, Development, Test, and Evaluations (5 percent).

Focus

Currently, slightly more than 800 PIPs are in process. Table C-17 shows the number and cost of PIP requirements by type.

TABLE C-17
ARMY PIP REQUIREMENTS
(October 1985)

Requirement	Number of PIP Proposals	Cost (\$ Billions)
Operational Capability	403	22.8
Operating Cost Reduction	33	3.9
Reliability and Maintainability	139	3.4
Safety	97	2.1
Other	137	1.3
TOTAL	809	33.5

Management

PIPs may originate in a wide variety of organizations, but final concept approval is accomplished by a joint review of Army Materiel Command, Training and Doctrine Command, and Headquarters, Department of Army. Once the concept is approved, the PIPs are placed in one of several categories of funding priority as

determined by Deputy Chief of Staff for Operations. The Army's Product Improvement Program is administered by Deputy Chief of Staff for Development, Engineering, and Acquisition, Program Integration Division, Army Materiel Command.

Criteria

PIPs are selected for funding based on a mix of criteria including mission need, safety, cost-effectiveness, and operating and support cost reduction. In recent years, annual funding has been dominated by large modification programs to improve the operational capability of major weapons systems.

Data Base

The Army does not use an automated data base in the management of the its Product Improvement Program.

Navy Aircraft Operational, Safety, and Improvement Program

Objective

The primary objectives of the Navy's Operational, Safety, and Improvement Program (OSIP) are: to improve aircraft operational capability, combat survivability, safety, and reliability and maintainability; and to sustain adequate aviation force levels by extending the service life or converting aircraft.

Charter

Information and guidance for the management of the Navy's OSIP is contained in Naval Air Systems Command Instruction 4720.6, "Aircraft Modification and Operational, Safety, and Improvement Program Procedures Manual," 2 December 1982.

Funding

Approximately 84 percent of the Navy's OSIP is funded by the Aircraft Procurement appropriation. The balance is funded from the Operations and Maintenance appropriation, and it is used to install the modification. While the aircraft procurement funds are used predominantly for acquisition of modifications, a small portion is also used to buy replenishment spares of modification material. The recent history of OSIP funding levels is shown in Table C-18.

TABLE C-18
NAVY OSIP FUNDING HISTORY
(\$ Millions)

Fiscal Year				
1985	1986	1987	1988	1989
2,052.9	2,478.3	1,864.7	1,737.7	1,719.0

As the table shows, OSIP funding has recently exceeded \$2 billion; the apparent decline in outyears represents a change in funding procedures, not a reduction in requirements.

Focus

The Navy's OSIP provides for four types of modification procurements. As shown in Table C-19, operational capability modifications command nearly two-thirds of all modifications procured (excluding spares and installation costs). Although safety modifications appear to be a small part of the OSIP program, they are also included in other categories in many instances.

TABLE C-19
NAVY OSIP MODIFICATIONS
(Fiscal Year 1987)

Type of Modification	Funding (\$ Millions)
Operational Capability	931.4
Reliability and Maintainability	325.1
Force Level	142.7
Safety	28.0
TOTAL	1,427.2

Management

OSIP requirements and priorities are established by the Office of the Chief of Naval Operations (OP-50). Program management is vested in Naval Air Systems Command (Air-102).

Criteria

OSIP modifications are selected for funding based on a mix of criteria including mission need, safety, reliability, and force-level requirements. The need for reliability and maintainability modifications is often indicated in 3M reports, Readiness Improvement and Status Evaluation reports, and other Fleet inputs.

Data Base

No automated data base is used in the management of the Navy's OSIP.

Air Force Product Improvement Program

Objective

The three objectives of the Air Force Product Improvement Program are to:

- Improve the cost-effectiveness, readiness, and safety of products in the Air Force operational inventory
- Prevent the recurrence of design deficiencies or extend the operational life of existing systems
- Maintain the combat effectiveness of operational weapons systems.

Charter

The policies for the Air Force Product Improvement Program are contained in Air Force Regulation 66-30, "Product Improvement Policy (PIP) for Operational Equipment," 8 February 1982. Procedures for planning, approving, and managing modifications to correct deficiencies or improve capabilities of existing equipment are delineated in Air Force Regulation 57-4, "Modification Program Approval and Management," 23 May 1983.

Funding

The Air Force Product Improvement Program is funded from four different appropriations: Aircraft Procurement; Other Procurement; Research, Development, Test, and Evaluation; and Operations and Maintenance. The actual funding level for modifications in FY86 was approximately \$2.0 billion, with total requirements in the range of \$5.5 billion to \$8.0 billion. In addition, another \$750 million in Operations and Maintenance funds was used for sustaining engineering (\$400 million) and installation of modifications (\$350 million). Some of the procurement funds are used for initial spares and for early replacement of unreliable components.

Focus

The Air Force Product Improvement Program provides for several types of procurements. These and the scope of funding are shown in Table C-20. The table shows that the Air Force's modification procurements are dominated by improvements in operational capability with 78 percent of the total. Excluding spares and replacements, operational capability is 93 percent of modification procurements.

TABLE C-20
AIR FORCE MODIFICATION PROCUREMENTS
(Fiscal Year 1986)

Type of Modification	Cost (\$ Millions)
Operational Capability	1,900
Reliability and Maintainability/Safety	100
Other	50
Initial Spares	80
Early Replacements	300
TOTAL	2,430

Management

The program office is Deputy Chief of Staff for Logistics and Engineering, Directorate of Maintenance and Supply, Aircraft Systems Division (AF/LEYY).

Criteria

Air Force modifications are funded primarily on the basis of user-certified mission need. Unreliable and unsupportable equipments are largely determined from Materiel Deficiency Reports and other data systems.

Data Base

No automated data base is used in the management of the Air Force's Product Improvement Program.

LOGISTICS RESEARCH AND DEVELOPMENT PROGRAM

General

Objective

The objective of the Logistics Research and Development (Logistics R&D) Program is to increase the R&D emphasis on weapon support and logistics through a funded program with the following goals:

- Reducing the logistics "tail" of deployed forces
- Reducing the maintenance cost of weapons systems
- Shortening the development cycle of new weapons systems
- Providing incentives to industry to invest in innovative support technologies.

Charter

The establishment of the Logistics R&D Program is attributable to two primary documents: Under Secretary of Defense for Research and Engineering memorandum entitled "Increased Readiness and Support," 1 March 1982, and Deputy Secretary of Defense memorandum for the Secretaries of the Military Departments, 26 May 1983.

Funding

Until recently, the Military Departments controlled all of the Logistics R&D funds. Now, OSD has responsibility for a portion of the funds through a special account established by the Defense Resources Board for weapon support and logistics

R&D. The scope of this split and the project funding for the near future are shown in Table C-21.

TABLE C-21
LOGISTICS R&D FUNDING
(\$ Millions)

Military Department	Military Department Funds		OSD Funds FY86
	FY86	FY86-FY90	
Army	33	98	15.1
Navy	31	152	11.0
Air Force	76	363	23.9
TOTAL	140	613	50.0

As the table shows, more than half of the Military Department funds is assigned to the Air Force; the balance, in FY86, is split almost evenly between the Army and Navy.

OSD Logistics R&D

Focus

The OSD-controlled portion of the Logistics R&D Program is focused on the development and demonstration of advanced technology for weapons system component failure diagnosis, automated technical information/maintenance aids, logistics systems, and equipment reliability and maintainability. A major thrust is toward demonstration of "integrated diagnostics."

Management

The OSD portion of the Logistics R&D Program is managed by the Weapon Support Improvement Office, Assistant Secretary of Defense (Acquisition and Logistics). This office also reviews and approves the Military Departments' Logistics R&D program plans. Individual project proposals for the Military Departments are

reviewed by the Weapons Support Technology Review Group, a committee composed of representatives from several offices and organizations.

Criteria

Many of the candidate projects for the OSD Logistics R&D Program stem from technology opportunities identified in a recent Reliability and Maintainability study completed for the Weapon Support Improvement Office. Selection of particular projects is based on the technical judgment of that office.

Data Base

No automated data base is currently used to manage the OSD Logistics R&D Program; one is under development, however.

Military Department Logistics R&D

The Logistics R&D Programs of the Military Departments were not reviewed in any depth.

SERVICE-UNIQUE PROGRAMS

Air Force Maintenance Sponsored Technology (MST) Program

Objective

The objective of the Air Force MST Program is to expeditiously introduce state-of-the-art equipment into the depot maintenance industrial complex.

Charter

The charter for the MST program is currently under development. When officially published, it will be incorporated into Air Force Logistics Command Regulation 78-3.

Funding

The funding goal for MST is determined as a percentage of the capital equipment portion of the ACP, which the Air Force terms the Depot Maintenance Equipment Program (DMEP). The goal of the Air Force is to set aside 10 percent of DMEP for its MST program.

Focus

The focus of the MST Program is on equipment projects that provide the transition between R&D efforts and existing DMEP requirements (off-the-shelf equipment).

Management

The office with primary responsibility for the MST Program is the Deputy Chief of Staff for Maintenance, Air Force Logistics Command. The focal point is the Directorate of Maintenance Engineering (AFLC/MAX).

Criteria

To be eligible for the MST Program, projects need to integrate current equipment with new technology or apply new technology to specific maintenance and repair operations. Also, MST projects must add no new maintenance capacity and must conform to current DMEP acquisition procedures. Automated data-processing systems are excluded from the MST Program.

Projects selected for MST funding must meet the following criteria:

- Satisfy a current or expected depot maintenance need for a new, improved or more economical manufacturing/repair process, technique, or equipment
- Require no research and development or prototype; implementation time must be relatively short
- Involve low or moderate technical risk
- Be economically feasible.

Data Base

No automated data base is used to manage the Air Force MST Program.

Air Force Productivity, Reliability, Availability, and Maintainability (PRAM) Program

Objective

The objectives of the Air Force PRAM Program are to reduce operating and support costs of weapons systems and increase combat readiness through improvements in reliability, maintainability, and supportability of equipment; and, in

productivity, effectiveness, and efficiency of organic maintenance and support organizations.

Charter

The PRAM Program is chartered by Air Force Program Management Directive R-P6067(4)78026F dated 11 April 1984 and is supported by the Air Force Systems Command and Air Force Logistics Command.

Funding

In accordance with Congressional direction, the PRAM Program is funded with RDT&E funds under a separate program element. PRAM funding has remained relatively constant in recent years but will experience a sharp upturn in FY87. The funding profile for the PRAM Program is given in Table C-22.

TABLE C-22

PRAM PROGRAM FUNDING PROFILE

(\$ Millions)

Fiscal Year				
1984	1985	1986	1987	1988
12.7	13.4	14.0	31.5	39.1

Focus

PRAM projects generally focus on the application of available technology to fielded systems. Projects are relatively short term (15 months), cost an average of \$250,000, and address areas that contribute to high operating and support costs, such as maintenance, operating, and training concepts; personnel and industrial productivity; procedural systems, such as materiel deficiency reporting, maintenance data collection system, and data information analysis systems; operational readiness improvements; and adaptability of equipment to broader applications.

Management

Policy and oversight are provided by the offices of the Deputy Chief of Staff (Research, Development, and Acquisition) and the Deputy Chief of Staff (Logistics and Engineering). The Air Force Systems Command and the Air Force Logistics Command are jointly responsible for the staffing and management of the PRAM Program Office. In addition to normal organizational relationships, a special General Officer steering group periodically reviews the activities of the PRAM Program, provides guidance to the PRAM Program Director, and approves all PRAM projects that require investment funding greater than \$500,000.

Criteria

The PRAM Program Office uses a mix of criteria in evaluating and selecting potential projects for funding, including improvement in reliability and maintainability, improvement in productivity, reduction in operating and support cost, return on investment, generic applicability, and technical risk. These criteria are applied subjectively and in no particular order of priority. However, no project is approved without a firm commitment for implementation from the user and the maintainer because the PRAM Program is only authorized to prototype or demonstrate.

Data Base

No automated data base is used to manage the PRAM Program.

Air Force Logistics Command PACER IMPACT Program

Objective

The objective of the PACER IMPACT (Industrial Maintenance Productivity Through Increased Accountability, Creativity, and Technology) Program is to achieve productivity growth in Air Force Logistics Command maintenance organizations through comprehensive and often high-risk, high-payback initiatives in multiple areas.

Charter

The charter for PACER IMPACT is currently under development; the program was initiated in October 1983.

Funding

PACER IMPACT does not provide funds to support any particular productivity or technology effort.

Focus

The primary focus of PACER IMPACT is to encourage the initiation, institutionalization, and tracking of productivity efforts. Heightened emphasis is placed on total management commitment and strategy.

Management

PACER IMPACT employs an interlocking organizational process and communications network superimposed on the existing maintenance organizations of the Headquarters, Air Force Logistics Command, and the air logistics centers. Guidance, control, and major project approval is provided by the Maintenance Productivity Steering Group, which is composed of the Deputy Chiefs of Staff for Maintenance from the headquarters and air logistics centers. The steering group is assisted by the Maintenance Task Force for Industrial Productivity, which is charged with developing plans, recommending projects, and evaluating development group progress. It is assisted by several staff working groups for publicity, communications, measurement, etc.

The Productivity Development Groups are committee-style organizations that work in five major areas: (1) Methods/Process Engineering, (2) Materiel/Asset Management, (3) Technology Enhancement, (4) Work Force Development and Motivation, and (5) Financial Management Integrity. Each Development Group is chaired by representatives from a different air logistics center, with each center

represented on every Development Group. Among their responsibilities, the Productivity Development Groups:

- Research, plan, and recommend new initiatives
- Catalog active and potential projects
- Develop short- and long-range plans
- Disseminate project status information.

Criteria

PACER IMPACT encourages the initiation, tracking, and institutionalization of productivity efforts but does not provide funds for technology and productivity programs or projects.

Data Base

No automated data base is used to manage the PACER IMPACT Program.

Air Force Logistics Command LIFT Program

Objective

The objectives of the Air Force Logistics Command Logistics Improvement of Facilities and Technology (LIFT) Program are to improve the command's productivity and efficiency, improve resource use, and increase readiness.

Charter

The LIFT Program is authorized by Air Force Logistics Command Regulation 78-7, "Instructions for Logistics Improvement of Facilities and Technology (LIFT)," 15 August 1984.

Funding

The LIFT Program does not provide any funds to support facilities and technology improvement efforts.

Focus

The focus of LIFT is on management planning and coordination of capital investments at organic industrial facilities. It fosters systematic analysis of work

center requirements, identification of deficiencies, and development of comprehensive corrective plans.

Management

The LIFT Program is managed by the Directorate of Maintenance, Air Force Logistics Command, which reviews, coordinates, and approves/disapproves the LIFT plans and summaries submitted by each of the centers. It also consolidates command funding requirements, defends approved plans, and allocates resources. These management actions are based on LIFT plans, project summaries, and matrices submitted by the centers. A LIFT plan defines the equipment, facility, and technology needs for a center while the project summary identifies specific projects to correct deficiencies. The matrix is an analytic tool that portrays a center's deficient areas by providing a graphic array of resources and constraints versus work center capabilities.

Criteria

The maintenance division of each air logistics center establishes its own criteria for including requirements and projects in the LIFT Program.

Data Base

No automated data base is used in managing the AFLC LIFT Program.

APPENDIX D

OVERVIEW OF UNNECESSARY REMOVALS IN DoD

BACKGROUND

Unnecessary removal is defined as the removal of line replaceable units (LRUs) from the end item [or shop replaceable units (SRUs) from the LRU] that have no apparent defect when they are subsequently checked out at the same or higher maintenance echelon for repair. That definition is a general one; each of the Military Services has adopted its own definitions and terminology. For example, the Air Force uses the following terms:

- Can Not Duplicate (CND): reported discrepancy cannot be verified at the organizational level; the item may or may not be removed.
- Bench Check Serviceable (BCS): removed LRU is found serviceable at the intermediate level.
- Retest Okay (RTOK): removed SRU or LRU is found serviceable at the depot level.

These three terms are often confused with each other. The Navy uses the terms No Fault Removals (NFR) and No-Defect Maintenance Actions that are defined in terms of specific Action Taken/Malfunction codes from the Navy's maintenance data system. The Army uses the term No-Evidence-of-Failure (NEOF). In addition, reported unnecessary removal rates may or may not include cannibalizations and other maintenance actions that are done on purpose.

Unnecessary removals primarily result from inefficient maintenance practices. They represent or include what is known in human factors terminology as Type I errors (i.e., declaring a good unit faulty; Type I errors have an economic impact. The opposite manifestation of inefficient maintenance is known as Type II errors (i.e., declaring a faulty unit good); Type II maintenance errors may result in mission aborts or accidents and, for that reason, their prevention has traditionally received more emphasis in equipment design than that accorded Type I errors. The two are, however, related. Reducing the probability of Type II errors generally requires tight tolerances for built-in test (BIT) hardware or software and conservative

serviceability criteria or standards. In turn, these tolerances and criteria increase the probability of "false alarms" (i.e., fault indications or out-of-tolerance discrepancies where none exist) and, thereby, the probability of Type I errors.

Since the introduction of modular design concepts in the 1960's and the associated remove/replace maintenance philosophy (in lieu of on-equipment repairs), the extent of unnecessary removals has grown with increasing complexity of equipment. Three facts are particularly noteworthy. First, the phenomenon has become widespread; it is not merely limited to the DoD but occurs in the private sector also. Second, it is not limited to electronics equipment but is also encountered in the maintenance support of mechanical equipment. Third, accurate data on the extent of unnecessary removals are difficult to collect; the current maintenance data collection systems of the Military Services do not provide an accurate picture. In sum, unnecessary removals appear to be a technology-driven maintenance attribute of modern equipment that is not well understood but is generating increased concern because of escalating support costs.

EXAMPLES

The following examples of unnecessary removal experiences are based on published sources. Although the data contained in these examples are at least a year old, there is no reason to believe that today's situation is materially different.

Commercial Sector

Two industry groups for which unnecessary removal statistics are readily available are the common air carriers and the electronic test equipment (ETE) industry. ARINC, a service organization owned by the domestic air carriers, collects and publishes many types of data, including industry-wide unnecessary removals of avionics equipment by type/model/manufacturer/aircraft. It recently reported that the unnecessary removal rates for different domestic carriers range from very low (10 percent and below) to very high (90 percent and above), with a preponderance in the 40 to 50 percent range [1]. Unfortunately, the report does not provide any comparative data by airline for the same equipment/aircraft installation. The improvements promised by the introduction of new-generation designs featuring more-integrated digital avionics (Boeing 757 and 767) cannot yet be confirmed by fleet data. ARINC reports that the average unnecessary removal rate has hovered

around 50 percent since the early 1960's, but is drifting upward, although a definite trend has not yet been established.

One airline, KLM Royal Dutch Airlines, reported that its unnecessary removal rate of avionics LRUs was 40 to 50 percent in 1980 [2]. At that time, KLM was maintaining approximately 1,300 different avionics LRUs for its fleet of Douglas DC-8, DC-9, and DC-10 and Boeing 747 aircraft. KLM estimated that the unnecessary removals increased costs by approximately \$7 million per year and concluded that most such removals could be attributed to diagnostic shortfalls in BIT.

Aircraft manufacturers also commonly monitor the maintenance data of their customers. Boeing, for example, estimates the average unnecessary removal rate among its customers at 30 to 40 percent for mechanical LRUs and 50 to 60 percent for electrical/ electronics LRUs [3].

The ETE industry supports its commercial test equipment with removal/ replacement of electronic modules (primarily circuit boards) in the field, either on-site by service engineers or at local service centers, and centralized repair of those modules. The average no-defect removal rate, reported by the ETE industry, is 30 to 50 percent [4]. In 1983, a representative large circuit board repair center, processing 18,000 boards of 350 different types, reported 30 percent no-defects for digital boards, 34 percent for analog, and 29 percent for hybrids, with an overall no-defect rate of 31 percent [5]. The ETE industry is very much aware of the tremendous cost associated with a no-defect rate of this magnitude. On a worldwide basis, hundreds of thousands of good circuit boards are in pipelines from local service centers to central repair centers, with an estimated avoidable cost in the billions of dollars. (Similarly, the amount of money tied up in the computer industry in "board float" was estimated to have increased from \$6 billion at factory cost in 1978 to \$9 billion in 1981 [6].) The ETE industry is now countering this situation by installing suitable automatic test equipment (ATE) to provide local screening of boards to prevent the return of no-defect boards to central repair sites.

U.S. Air Force

The Rome Air Development Center (RADC) recently sponsored a comprehensive study of the extent and causes of unnecessary removals of avionics equipment. That study looked at six representative common avionics subsystems

installed aboard Air Force fighter, bomber, attack, and transport aircraft. Using contractor-validated data for 1981, it found an average unnecessary removal rate of 33 percent for the six subsystems[7]. The study also provided recommendations that, if implemented, could reduce this rate to approximately 10 percent.

Other Air Force examples include data peculiar to the F-111, F-15, and F-16 fighter aircraft.

F-111

First fielded in 1967, the F-111 fleet comprises about 400 aircraft in six different configurations. An avionics upgrade program is currently underway as a result of the Air Force's decision to extend the service life of this aircraft into the next century. Throughout its first 15 operational years, F-111 maintenance was plagued by inconsistencies in automatic test results at the organizational and intermediate maintenance levels. The unnecessary removal rate for the F-111 avionics suite was estimated to be as high as 52 percent as recently as 1981 [8]. In the late 1970's, the Sacramento Air Logistics Center (ALC) developed a "dynamic test station" to supplement the 10 different ATE stations fielded in the Avionics Intermediate Shop (AIS). A prototype was tested in 1981 and resulted in the BCS rate being reduced from 52 to 28 percent (i.e., LRUs removed from the aircraft but found serviceable when tested on the ATE were actually faulty). Furthermore, one-third of the LRUs that the old ATE passed as good after they had been repaired at the AIS were found to be still defective when tested on the dynamic test station (see illustration in Figure D-1)[9]. The latter LRUs caused persistent problems in the past because they did not work in the system environment (aircraft) but faults could not be detected at the AIS, making repair impossible and causing uncertainty about BIT indications. The Air Force is now fielding these dynamic test stations in conjunction with the F-111 AIS replacement program. Importantly, without those dynamic test stations, the ATE fielded with the AIS replacement program would have perpetuated the diagnostic difficulties and high unnecessary removal rates.

F-15

The first F-15 wing was activated at Luke Air Force Base in 1974. A complete AIS capability was not available until 1977. In 1979, the prime contractor conducted a comprehensive study of the automatic testing problems (both BIT and ATE) reported for the F-15. It found a CND rate of 43 percent (not necessarily resulting in

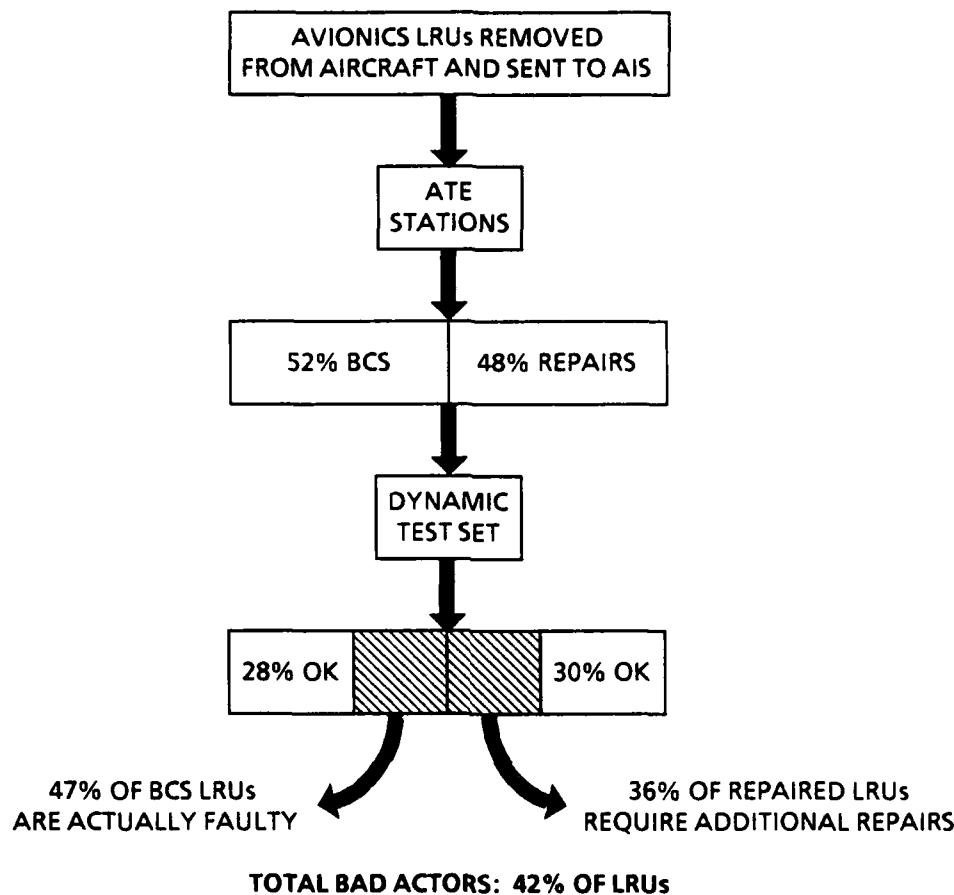


FIG. D-1. F-111 AVIONICS TEST DATA

LRU removals) and a BCS rate of 30 percent (i.e., 30 percent of the LRUs removed from the aircraft to the AIS tested serviceable) [10]. The same study also found that the Air Force's maintenance data collection system was underestimating the extent of unnecessary removals (it showed a BCS rate of 22.7 percent versus the 30.4 percent actually experienced). The contractor also analyzed the causes for unnecessary removals and recommended a number of corrective actions, including engineering changes, additional troubleshooting training for maintenance personnel, better procedures for ATE operators, and increased pilot familiarity with normal system operations. If all the recommendations were adopted, which they were not, the contractor estimated that the BCS would drop to 15 percent. Continued support problems with the F-15, especially the AN/APG-63 radar system, caused the Warner Robins ALC to create, in 1980, an "F-15 RTOK Management Group" to analyze and

correct automatic testing deficiencies. Data accumulated by that group showed, in 1982, unnecessary removal rates of 27 percent for radar LRUs and 21 percent for SRUs [11]. Further inquiries indicate that ATE operators in the F-15 AIS follow work-around procedures to compensate for shortcomings in the ATE and test program sets (TPSs). Furthermore, Warner Robins ALC does not possess the technical data to improve known deficiencies in the TPS for LRUs [12]. The F-15 avionics upgrade program and associated AIS replacement program may alleviate these problems.

The first aircraft from the F-15 Multistage Improvement Program (MSIP) was delivered to the Air Force in June 1985. One of the major improvements is the installation of a digital electronic engine control (DEEC) on the Pratt & Whitney F100 engine. Operational tests of F-15s powered by DEEC-equipped engines are currently in progress and, reportedly, show favorable results compared to the previously installed nondigital electronic engine controls. Apart from the operational improvements (quicker acceleration, unrestricted throttle movement throughout the flight envelope, smoother ignition of afterburner), the DEEC has a continuous trim feature that automatically adjusts the engine's thrust at all airspeeds/altitudes to compensate for gradual aging of hardware. This eliminates the need for a periodic "trim check," currently one of the most common maintenance tasks for the engine, thus reducing maintenance man-hours. Furthermore, the DEEC is designed to isolate faults in engine operation and identify the specific components that require attention (adjustment or replacement). It will also be installed on the advanced F100-PW-220 engine. Quantitative data on DEEC fault isolation performance, however, are not currently available.

F-16

In contrast to the F-111 and F-15, only a portion of the F-16 avionics LRUs are processed through the intermediate shop, with the rest evacuated to depot for repair. Based on extensive analysis and trade studies, about 39 of 110 avionics LRUs were allocated to the AIS; those tend to be the more costly and complex LRUs [13]. (This is just the opposite from the Army's approach where complex LRUs are normally allocated to intermediate-rear or depot levels.) The first production F-16 was delivered to the Air Force in August 1978, and the first squadron was activated in 1979. Interim contractor support was provided through 1981, when the Air Force attained full AIS and organic depot maintenance capability. In its Follow-On

Operational Test and Evaluation, conducted between January 1979 and June 1980, the Air Force Test and Evaluation Center evaluated the F-16's automated diagnostics and reported the following [14]:

- Flight Control BIT: fault detection capability 83 percent, CND rate 17 percent, fault isolation capability 74 percent, RTOK rate 20 percent.
- Multiplex Bus: fault detection capability 49 percent, CND rate 46 percent, fault isolation capability 69 percent, RTOK rate 26 percent.

For both systems, the reported RTOK rate actually refers to a BCS rate; thus, unnecessary removals in the operational test environment (net of false alarms, CNDs, and "nonchargeable" faults) were estimated to be between 20 and 26 percent. More recent data on the APG-66 radar indicate an unnecessary removal rate for LRUs of 34 percent [15]. This result was obtained after several blocks of improvements in BIT had been fielded. Importantly, the F-16 system program office funded the development and installation of the "Centralized Data System," which is an on-line data system for the F-16 fleet providing daily reporting of both aircraft and AIS status and maintenance actions. This data system has enabled rapid identification of testing problems and development of corrective actions.

U.S. Navy

Shipboard Systems

The Navy's maintenance concept for combat systems aboard surface combatants and attack submarines is essentially a two-level concept: organizational (shipboard) maintenance removes/replaces faulty modules that are sent to depot maintenance for repair. Electronic systems installed in submarines are built primarily from standard electronic modules (SEMs) that are form/fit/function-standardized circuit boards. As a result, maintenance personnel must rely primarily on BIT, because there is little or no off-line test equipment (manual ETE or ATE) aboard the submarine. Since systems installed aboard surface combatants may or may not include SEMs, maintenance personnel use a mixture of BIT indications and manual troubleshooting procedures using common ETE. The replaceable items either consist of circuit boards or LRUs that are packages of several circuit boards. In 1981, the no-defect rate of modules and circuit boards received from the Fleet at Navy depot activities was about 30 to 50 percent for modules and 60 to 80 percent for circuit boards [16]. To correct this situation, the Naval Sea Systems Command

initiated, in 1978, the Support and Test Equipment Engineering Program. Under that program, the Navy installed circuit board testers at intermediate maintenance activities and aboard selected surface combatants. The first testers and associated TPSs were fielded in July 1981. This program is scheduled to continue into the early 1990's with several hundred unique TPSs fielded each year [17]. The reduction in serviceable circuit boards returned to depots, however, lags the fielding of this testing capability at intermediate levels because the Fleet must get accustomed to the revised procedures and the source/maintenance/recoverability codes for the boards involved must be changed. For example, in 1983 only 25 percent of the Fleet followed the new procedures, with the remainder continuing to evacuate circuit boards directly to depots.

Naval aviation has a three-level maintenance concept similar to that of the Air Force, except that SRU [or shop replaceable assembly (SRA) in Navy terminology] repair also takes place at the intermediate maintenance level. Three case examples are the F-14A, the S-3A, and the F/A-18.

Aviation Systems

F-14A. The first production F-14A aircraft were delivered to the Navy in 1972, and the first two operational squadrons were deployed in 1974. In 1982, the Navy had 20 F-14 squadrons of 12 aircraft each. In 1984, the Navy initiated the F-14D upgrade program. Currently, it plans to field 70 F-14A + (re-engined F-14A) aircraft and 300 F-14D aircraft.

A detailed study of F-14 maintenance data from 1977 showed that the Type I error rate for all F-14A avionics amounted to 14.5 percent, excluding any unnecessary removals done on purpose, such as cannibalizations and removals for accessibility [18]. For certain subsystems such as the AN/AWG-9 radar, the same study found a Type I error rate of 21 percent. A more detailed study of the AWG-9 radar maintenance data, using the Naval Aviation Logistics Data Analysis data

base for the 20-month period of January 1981 through September 1982, was completed in 1984 [19]. That study resulted in the following findings:

- About one-third of reported organizational maintenance actions are cannibalizations that are performed either because of supply shortages and/or distance to the supply room or as a troubleshooting work-around procedure.
- About 50 percent of the cannibalization actions are not reported. Virtually all weapon replaceable assembly (WRA) removals for cannibalization, however, stay at the organizational level and do not result in additional workload for the intermediate level.
- Of the AWG-9 WRAs received at the intermediate level, 10 to 60 percent showed no defect depending on WRA, with a weighted average of 30 percent.
- Conversely, about 10 percent of the WRAs repaired at the intermediate level did not work when installed in the aircraft.
- Overall, the actual number of maintenance actions (including cannibalizations) per verified failure was approximately 7, thus causing the AWG-9 radar to appear more unreliable than it actually was.

The unnecessary removal rate for the AWG-9 radar system, including cannibalizations, was therefore assessed at 85 percent; if only reported cannibalizations are included, then the rate was closer to 60 percent; if cannibalizations and other removal actions not impacting on the intermediate level are excluded, then the BCS rate was 30 percent. The Navy reports, however, that recent improvements have resulted in a reduced unnecessary removal rate.

S-3A. The S-3A is a carrier-based antisubmarine warfare (ASW) aircraft. It was introduced in 1974, with first operational deployment in 1975. The S-3A is deployed in a ten-unit squadron, with one squadron per carrier. In 1982, the Navy initiated the S-3B upgrade program with major changes in avionics equipment and payload.

As in the case of the F-14, about one-third of all avionics WRA removal actions are coded as cannibalization actions. Excluding those, the unnecessary removal rate of avionics WRAs confirmed as BCS at the intermediate level has been estimated at 21 percent [20]. More recent Navy data for 1985 show an unnecessary removal rate of 27 percent for the S-3A's integrated guidance/flight controls system [21].

F/A-18. The F/A-18 entered Fleet service in 1981, with the first operational squadron being commissioned in 1983. Although the F/A-18 program received major emphasis in reliability and maintainability aspects, the AN/APG-65 radar BIT has not performed as well as expected. As of May 1983, the BIT false alarm/false detect rate was between 45 percent (contractor data base) and 62 percent (Navy data base), yielding an unnecessary removal rate of 40 to 50 percent [22]. More recent data from 1985, however, show an unnecessary removal rate ranging from 24 percent (weapons control) to 50 percent (autopilot). Importantly, the integrated BIT architecture and in-flight recording of fault symptoms permit a change in maintenance concept, consisting of an automatic test set at the organizational level that interrogates BIT memory and thus isolates about 75 percent of all avionics failures to an SRA and reduces both the unnecessary removals of WRAs and the workload on the intermediate-level ATE. This concept has been adopted by both the Australian and Canadian Air Forces but not by the U.S. Navy.

U.S. Army

The Army's Applied Technology Laboratory has sponsored numerous studies of diagnostic shortfalls and resulting maintenance inefficiencies as well as the actions required to correct them. One of those studies examined the validity of diagnostic devices and techniques used to evaluate actual or pending failures of mechanical components (helicopter engines, transmissions, and gearboxes) and to decide on removal of such components. Using a data base spanning several years, it reported the following invalid removal rates (with invalid removals defined as removed components for which no defects were found upon teardown for failure or nonfailure modes so that the components could have remained in service) [23]:

- T53 engines (UH-1, AH-1, and OH-58 helicopters): 23 percent
- Transmissions: 38 percent
- Gearboxes: 46 percent.

One of the diagnostic techniques used for detecting pending failures in oil-wetted components such as engines, transmissions, and gearboxes is the Army Oil Analysis Program (AOAP). Under that program, oil samples are taken every 25 operating hours (now being extended to intervals of 50 or 75 operating hours) and sent to one of seven Army laboratories [five in the Continental United States (CONUS), one in Federal Republic of Germany, and one in Republic of Korea] for

analysis. The effectiveness of the program, however, is in doubt. A separate analysis of the available data through mid-1980, conducted by a helicopter engine manufacturer, came to the following conclusions [24]:

- The AOAP is 43-percent effective for the T53 engines (37-percent effective for the T55 engines) in identifying actual engine problems.
- The AOAP does not identify 50 percent of the T53 problems (61 percent of the T55 problems) that it should identify.

The AOAP at that time (mid-1980) consisted only of spectrometric oil analysis, and particles over 8 microns in diameter could not be detected. Since then, the AOAP has been extended to include ferrographic analysis to detect such larger particles. Nevertheless, the Applied Technology Laboratory believes that the Army should be more discriminating in its use of AOAP and limit its application, as the other Military Services do, to those cases in which it has proven effective [25].

Another reason for invalid removals is provided by overly conservative serviceability criteria and standards that have been established because of inadequate condition monitoring devices. For example, helicopter transmissions and gearboxes are removed for overhaul at fixed time intervals. (Since 1980, the T53 engines are maintained under an "on-condition" maintenance concept.) One of those monitoring devices is the chip detector system aboard Army helicopters, comprising oil filters, chip detectors, and a cockpit warning light. The lack of effectiveness of that system, as currently installed, has been documented in several studies, with the conclusion that only 12 percent of the indications result in valid component removals [26]. The remaining 88 percent of chip warning light occurrences are nuisance indications that cause significant problems in the operation and support of helicopters. For example, pilots are supposed to make a precautionary landing when the indicator lights up, an oil sample must be drawn and analyzed, and the components involved are frequently removed from the aircraft either to await oil analysis results (which takes an average of 2 weeks) or to return them to depot for inspection. The Applied Technology Laboratory sponsored the development and demonstration of a better chip detector system (using different filters and burn-off chip detectors), eliminating most of the nuisance indications. The new system provides significant advantages: it enables on-condition maintenance of transmissions, increases the time between component removals, reduces no-fault removals, increases oil change intervals, increases bearing and gear life, and improves mission

reliability [27]. It would also permit removing the chip warning light from the cockpit and installing it in the maintenance bay, thus eliminating the primary cause for excessive precautionary landings. The Army has not yet decided if and when to install this new system.

While unnecessary removals of many mechanical components are unavoidable under current diagnostic procedures and techniques, the Army is encountering additional problems with the return of helicopter components from U.S. Army Europe (USAREUR) to CONUS, primary in the area of transportation costs and delays. For example, the Corpus Christi Army Depot reports that between 20 and 30 percent of all engines that are returned from USAREUR activities can be repaired at field-maintenance levels. Reportedly, a budget of \$100,000 had been requested each year since the mid-1970's for the construction and fielding of a mobile engine test stand, but that request has not been funded by the Army [28]. (Currently the one engine test stand in USAREUR is fully occupied testing CH-47 T55 engines.)

With regard to electronic components, most circuit boards deployed in Army systems are removed/replaced at the intermediate maintenance level and returned to either CONUS depots or in-theater Special Repair Activities such as the Pirmasens Communications-Electronics Maintenance Center. The no-defect rates of circuit boards received at these types of activities have been reported to range from 20 to 30 percent, but the samples are rather small. The two CONUS depots responsible for circuit board repair, Tobyhanna Army Depot and Sacramento Army Depot, are currently conducting a study of the extent and causes of no-defect boards. The Maintenance Directorate of each depot provided the following data [29]:

- Tobyhanna supports the repair of 60 percent of the Army's circuit boards. It does not collect statistics on no-defect rates, but recently conducted a controlled experiment (sample size 300 boards) demonstrating a no-defect rate of 10 percent. Most of the boards involved came from TACFIRE, which is supported at the intermediate level with a hot mockup that provides an effective screening capability, thus explaining the low no-defect rate.
- Sacramento supports repair of the remaining 40 percent of the Army's circuit boards, about 400 different types at present. It processes 7,000 boards per month. Although it does not collect statistics on no-defect rates, its shop personnel estimate the no-defect rate ranges from 10 percent to 25 percent, depending on the end item involved. Electro-optics boards tend to be at the high end (20 to 25 percent no-defect rate), ground radar

boards at the low end (10 percent), and avionics and ground radio items in between.

These data, especially those from Sacramento Army Depot, indicate that maintenance personnel at intermediate maintenance levels, using ATE and TPSs for LRU fault isolation, are successfully identifying the faults. Current TPSs typically leave an ambiguity group of three to five SRUs that must be manually probed (often guided by instructions displayed on the MSM-105 video display terminal from fault dictionary data) to find the faulty board. Although some of this work is performed by civilians (about 40 percent according to Army spokesmen), the data indicate the Army has a considerable organic capability in the use of ATE/TPSs for LRU fault isolation.

In another study, the unnecessary removal rate for the Improved HAWK (IHAWK) missile system was estimated to be approximately 40 percent, based on maintenance data and on-site visits to many IHAWK batteries in 1979 [30]. Since that time, the Army has fielded an automatic tester to screen removed LRUs/circuit boards before they are returned to a Specialized Repair Activity for repair. It has also improved course entrance prerequisites and a program of instruction for IHAWK maintenance personnel. These actions, combined with on-going hardware improvements in the IHAWK system and increased management emphasis on maintenance improvements, have resulted in a reduction of the no-defect removal rate to 18 percent as of early 1985 [31].

Another example is the M65 Airborne TOW Missile System that is installed in the AH-1S helicopter. Although the system is not complex (comprising only nine LRUs), its BIT has not been very successful [32]. Because the off-line semi-automated test equipment (the Test Set Guided Missile System) is operationally unsuitable, the TOW Missile System had a unnecessary removal rate of approximately 45 percent until 1981 [33]. Since 1981, the corps aviation intermediate maintenance unit has started a screening procedure, using an AH-1S helicopter as a flying test bed if necessary, before items are sent elsewhere for repair [34]. As a result, the no-defect rate of M65 items has declined to approximately 25 percent. The long-term answer to this problem is to field the maintenance aid that was successfully demonstrated, eliminating the need for the expensive test set (\$350,000), reducing the unnecessary removal rate to zero, and improving the maintenance turnaround time and operational readiness. The Army has not taken that

action. The current TOW II improvement program was undertaken to improve the missile performance, not to correct the diagnostic shortfalls of the system.

Data on diagnostic shortfalls, but not unnecessary removal rates, for other Army systems (including M1 tank, M2/M3 Fighting Vehicle Systems, TSQ73 Missile Minder, PATRIOT, AH-64 APACHE, AN/GSG-10 TACFIRE, and UH-60 BLACK HAWK) are documented in another recent report [35].

CAUSES

The causes for unnecessary removals are varied. The RADC-sponsored study on Air Force avionics, which is probably the most thorough study on the subject to date, assessed the causes as follows in descending order of importance (percentage of unnecessary removals caused):

- Ineffective BIT (22 percent)
- Ineffective or missing ETE (18 percent)
- Ineffective supervision (16 percent)
- Ineffective technical manuals (13 percent)
- Lack of accessibility (12 percent)
- Management directives (7 percent)
- Test equipment incompatibilities (7 percent)
- Inadequate skills (5 percent)
- Inadequate feedback of information (1 percent).

The mix of causes may well be representative for the Air Force. For Naval aviation, however, the operating tempo may be more of a factor because it invites cannibalization as an expedient procedure for turnaround maintenance. Furthermore, cannibalization is a practical necessity to reporting high readiness rates. For Naval surface systems, BIT limitations combined with the absence of card testers and test programs are the primary causes, with ineffective technical training probably the third-ranked cause. In the case of the Army, diagnostic shortfalls (BIT limitations and unsuitable test equipment), inadequate training and experience of maintenance personnel, and inadequate technical manuals appear to be the preponderant causes.

CONCLUSIONS

The information and findings presented in this appendix yield a number of conclusions that point to the need for major improvements in the management of post-fielding weapon system support.

The Extent of Unnecessary Removals Is Significant

Weapon systems fielded in the 1970's exhibit a consistent pattern of unnecessary removals. The percentage of no-defect removals of LRUs from a weapon system ranges from 20 to 80 percent. The percentage of LRUs that test serviceable at the intermediate maintenance level ranges from 15 to 60 percent. The percentage of LRUs/SRUs that test serviceable at the depot level ranges from 10 to 80 percent. A DoD-wide average unnecessary removal rate is unavailable, however, and would be difficult to develop.

The Trend in Unnecessary Removals Is Upward

The current inventory includes systems fielded in the mid-1960's or earlier that were designed for on-equipment repair. As a result, the unnecessary removal rates for such systems are low. The inventory also includes many systems that have just been fielded; those systems tend to have substantially higher (than the older systems) unnecessary removal rates that may decrease over time as a result of corrective actions. Overall, the net effect DoD-wide is an upward trend of unnecessary removal rates resulting primarily from the steady modernization of equipment.

Advanced Technology Will Compound the Problem

Investigations of future weapon system technology reveal at least three trends that will compound the problem of unnecessary removals, at least for the foreseeable future.

The first trend is the increasing electronics content of weapon systems. In the 1950's, the electronics content (cost basis) averaged between 10 and 20 percent. In 1973, the average electronics content was estimated at 26 percent [36]. In the early 1990's, the average electronics content will reach the 40-percent level [37]. The unnecessary removal rate for electronics systems tends to be higher than that for mechanical systems, all other factors being equal.

The second trend is the increasing complexity (density and interconnectivity of parts) of microelectronics technology. Advanced technology such as very large scale integration technology and very high speed integrated circuits (VHSIC) will be applied in the next generation of weapon systems even though these advances have outpaced testing technology. Serious engineering challenges remain to be solved in order to ensure those systems will be testable. A recent study [38] concluded that diagnostics must be improved if advanced technologies are to be successfully applied:

With these technology improvements, the complexity of systems will compound the problems of CNDs and BCSs unless considerable progress is made in the area of diagnostics. The notion that the more advanced technologies like VHSIC will solve reliability problems through the use of redundancy will not be effective unless accompanied by major improvements in diagnostics. . . . The implications are clear -- a discipline must be developed comparable to that developed for the reliability area over the past several years [39].

The third trend is the increasing sensitivity of new technology chips to the environment, as evidenced by increasing problems with component degradation caused by electrostatic discharge [40]. The degraded parts exhibit "soft" failures that are difficult to troubleshoot. As a result, they may escape standard acceptance test procedures and thus enter the supply system with unknown consequences [41].

The Consequences of Unnecessary Removals Are Difficult To Measure

Unnecessary removals increase maintenance workload, reduce operational readiness, and increase support costs. Quantitative data are not available on the first two consequences, but some estimates have been reported on the third. For specific subsystems analyzed, the increase in support cost has been estimated at several million dollars per year [42]. On a DoD-wide basis, unnecessary removals may thus escalate support costs by hundreds of millions of dollars annually.

The Causes for Unnecessary Removals Are Varied

Unnecessary removals cannot be attributed to a single cause. Causes include shortcomings in the weapon system hardware and software (poor design for testability, BIT limitations), the operational environment, inadequate test equipment and technical data, local management and supervision, and personnel/training factors. The particular mix of causes responsible varies from case to case. Diagnostic shortfalls explain approximately half of the unnecessary removals.

The Standard Maintenance Data Systems Do Not Provide Adequate Visibility

The maintenance data collection systems instituted by the Military Services are not designed to generate the management reports needed to monitor the extent of unnecessary removals, underestimate the extent of unnecessary removals, or both. In particular cases, the Military Services have established special, weapons system-dedicated, closed-loop maintenance data reporting systems that have been effective in measuring unnecessary removals accurately and collecting the information needed for analyzing the causes. Such special monitoring procedures, however, are typically short-lived, often terminated within a few years.

Corrective Actions Can Be Effective But Require a Concerted Approach

For high-priority weapon systems plagued by unnecessary removals, corrective actions are ultimately taken to reduce the severity of the problem. To the extent such actions address the diagnostic shortfalls (by improving BIT, adding or replacing ATE, or improving manual troubleshooting procedures in technical manuals), they can be effective in eliminating one of the causes for unnecessary removals. The chief problem, however, is the long delay before such actions take effect; for example, the Air Force took 18 years for the F-111, the Navy took 10 years for the BQQ-5 sonar[43], the Army took 12 years for the IHAWK, and further actions are still necessary.

To the extent other causes are responsible for unnecessary removals, such as personnel and training deficiencies, corrective actions have either been limited or ineffective. Both the delays and limitations of corrective actions indicate serious weaknesses in postfielding integrated logistic support (ILS) management. The needed actions are outside "standard" management procedures and require the weapons system-oriented ILS management process to be extended into the operational phase of the weapons system life cycle.

Further Initiatives Are Required

The Under Secretary of Defense for Research and Engineering has taken several initiatives in recent years to improve the effectiveness of automatic diagnostics. For example, a major R&D emphasis has been placed on "design for testability," "smart BIT," and "integrated diagnostics." Furthermore, the concept of "BIT maturation" during interim contractor support in the operational phase has

been well-established. These initiatives point in the right direction and will reduce the unnecessary removals for future systems resulting from diagnostic shortfalls. That is, however, only part of the problem. Those initiatives should be supplemented by actions taken by the Assistant Secretary of Defense (Acquisition and Logistics) to address the balance of the problem (unnecessary removals caused by factors other than diagnostic shortfalls) and, particularly, the currently fielded weapons systems that are exhibiting high unnecessary removal rates.

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APPENDIX E

WEAPON SYSTEM MASTER PLANNING PROCESS

This appendix describes the weapon system master planning process that was recently developed by the Air Force Logistics Command (AFLC) and approved for implementation by the Headquarters, U.S. Air Force.

CONCEPT

The concept of a weapons system master plan was developed by the Logistics Operations Center (LOC), a special activity of AFLC, in recognition of the need for a better management process to ensure that weapons systems achieve their required operational (combat) effectiveness. Existing procedures, such as integrated logistic support (ILS) plans, weapons system reviews, and logistics program assessment reviews, were recognized as not meeting that goal. The master plan is designed to identify the improvement programs needed to meet mission requirements, based on a detailed analysis of the existing support posture for a fielded weapons system, and to provide the funding profiles for implementing those improvements. It covers both product improvements (sustaining engineering, modification programs, and replacement equipment) and support improvements (replenishment spares, maintenance facilities and equipment, and infrastructure).

STATUS

The LOC published a planning guide in November 1985. Since then, prototype plans for 12 major aircraft fleets managed by AFLC have been completed. In addition, master plans for weapons systems managed by the Air Force Systems Command and for nonmajor systems under AFLC management are scheduled for December 1986. Following Headquarters, U.S. Air Force, approval, a program element monitor is being assigned; the process is being incorporated into an Air Force Regulation; and a study by Air Force Acquisition Logistics Center is underway on the potential consolidation of ILS and Weapon System Master Plans. A detailed specification of the measures to be used in system support analysis, however, has not yet been issued.

PLANNING GUIDE

A copy of the planning guide published by LOC is attached.

**WEAPON SYSTEM MASTER PLAN
PLANNING GUIDE**

EDITION ONE

1 NOVEMBER 1985

**OPR: LOC/AT
MAJOR H. MASON
787-2510**

EXECUTIVE SUMMARY

This Weapon System Master Planning Guide is an outline for use in developing Weapon System Master Plans (WSMP). A WSMP is an integrated document that defines the future support plans for a weapon system managed by AFLC, based on the projected threats and operational requirements. It integrates support requirements and develops support funding profiles. The Weapon System Master Plans emphasize coordinated projections for enhancing combat capability, survivability, reliability and maintainability. The plan draws from USAF and MAJCOMs' projections of operational requirements and identifies the resources, modifications and technology insertion/transition opportunities needed to support the system and its missions. Weapon System unique AFLC infrastructure requirements are also included to present a comprehensive overview of weapon system support requirements.

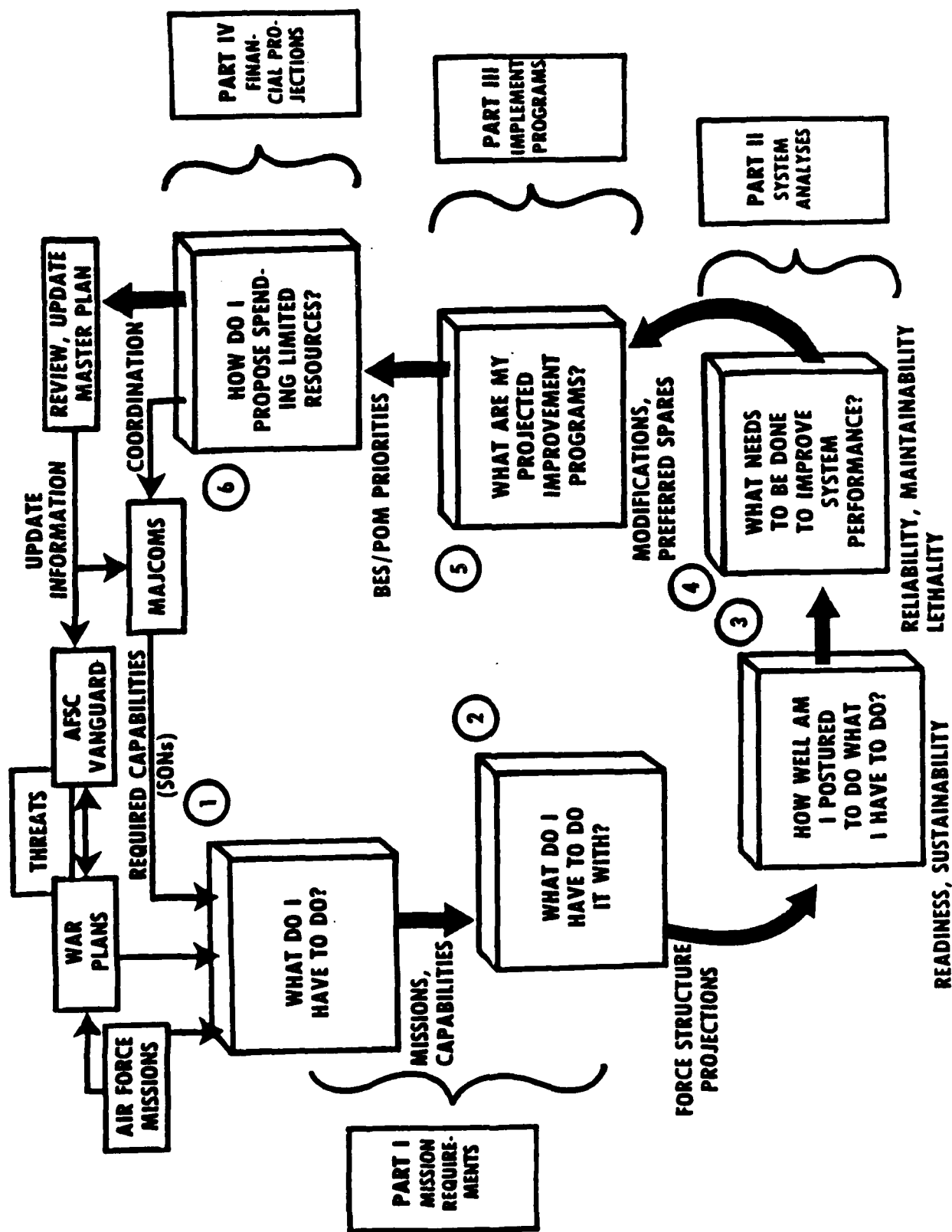
PURPOSE

The purpose of a Weapon System Master Plan is to assure the maximum effectiveness of the Weapon System in anticipated future wartime employments, and to accomplish this in the most cost effective manner consistent with operational necessity. This document will provide planners and programmers with a responsive plan that considers changing threats and mission requirements, projects these requirements along with technological opportunities, and provides support planning information to ensure the availability and supportability of the weapon system for future wartime employment. Specifically, the objectives of the Weapon System Master Plan are:

1. To provide managers with sufficient data on which to base advocacy positions.
2. To allow support plans to be based on an assessment of future threats and operational mission requirements.
3. To provide managers with current employment and support requirements to allow effective resource allocation, and modification development / integration consistent with changing weapon system long range needs and employment concepts.
4. To implement the requirements of R and M 2000.

PHILOSOPHY

This WSMP Guide is designed as a comprehensive outline of areas which should be included in the WSMP. The plan will not be limited to those items listed, but should contain all referenced areas unless they are not applicable to the specific weapon system. Many of the listed items of information are found in other plans and documents. It is not the intention to have them duplicated in a WSMP. Rather, the WSMP should emphasize the essential elements of long range support planning. It is anticipated that only information required to explain weapon system requirements and plans will be included.



WEAPON SYSTEM MASTER PLANNING GUIDE

I. WEAPON SYSTEM EMPLOYMENT REQUIREMENT PROJECTIONS

What are the missions I have to accomplish with this system?

(Classified portion of plan containing employment guidance)

1-1 The Mission

1-1-1 War plan(s) requirements summary

1-1-1-1 Objectives

1-1-1-2 Measures of merit (ton-miles, targets killed, launch reliability, etc.)

1-1-1-3 Deployment requirements

1-1-1-3-1 Theatres of operation

1-1-3-1-1 Characteristics

1-1-3-1-2 Unique problems

1-1-2 Out year projections (FYDP plus 3 years)

1-1-2-1 Probable mission trends/changes

1-1-2-1 Probable changes in objectives/measures of merit

1-1-2-2 Projections of changes in threats

1-1-2-3 Probable changes in roles and missions

1-1-2-4 Probable changes in theatres of employment

1-2 Required Capabilities

1-2-1 Requirements

Source:USAF Planning Document, MAJCOMS,
AFSC Vanguard plans

1-2-2 Statements of Operational Needs summaries

II. WEAPON SYSTEM EFFECTIVE ANALYSIS

2-1 Readiness / sustainability analysis

2-1-1 Force Structure projections

*** What is my force now and what does it need to be?***

2-1-1-1 Asset position forecast- airframe

2-1-1-1-1 Attrition

2-1-1-1-2 Test (missiles)

2-1-1-1-3 Retirement

2-1-1-1-4 Service life extensions

2-1-1-1-5 Concerns, analysis

2-1-1-2 Asset position forecast - engines

(same sub-areas as 2-1-1-1)

2-1-2 Availability

How ready is my fleet, and what are future requirements?

2-1-2-1 Mission capable/mission availability trends

2-1-2-1-1 Aircraft

2-1-2-1-2 Engines

2-1-2-2 Analysis

2-1-2-2-1 Aircraft

2-1-2-2-2 Engines

2-1-3 Accuracy (missiles)

***How accurate are the weapon delivery systems
and what are future requirements?***

2-1-4 Reliability and Maintainability (R and M 2000 Plan)

***How reliable and maintainable are the weapon system and its
components now; and what are the future needs?***

2-1-4-1 General operating needs and concepts

2-1-4-1-1 Using commands R and M priorities

2-1-4-1-2 Current R and M analysis methods

2-1-4-1-3 Weapon system R and M cycle

2-1-4-2 Reliability Program analysis summaries

2-1-4-2-1 Systems/components (non-structural)

2-1-4-2-1-1 Problem item analysis

2-1-4-2-1-2 Status

2-1-4-2-1-3 Forecasts by subsystems

2-1-4-2-1-4 Goal determination

2-1-4-2-1-5 Software considerations

2-1-4-2-1-6 Resources required

2-1-4-2-1-7 Life Cycle Cost Analysis

2-1-4-2-1-8 Technology insertion opportunities

2-1-4-2-2 Airframe

(same sub-areas as 2-1-4-2-1)

2-1-4-2-3 Engines

(same sub-areas as 2-1-4-2-1)

2-1-4-3 Maintainability Program action summaries

2-1-4-3-1 System/components (non-structural)

(same sub-areas as 2-1-4-2-1)

2-1-4-3-2 Airframe

(same sub-areas as 2-1-4-2-1)

2-1-4-3-3 Engines

(same sub-areas as 2-1-4-2-1)

2-1-4-4 Additional R and M initiatives

2-1-4-5 Necessary improvements

2-1-5 Test and assessment summary

***What are reports and analysis of Weapon System O,T and E,
Qual Tests, etc., showing are problems?***

2-1-6 Major Support Equipment Requirements

***What is my current support equipment posture and what
do I project?***

Source: LOC/CF, AFSCR/AFLCR 800-5

2-1-6-1 Analysis

2-1-6-2 Get well options

2-1-6-3 Plans for reducing requirements

2-2 Survivability

How survivable is the system and its support structure?

2-2-1 System vulnerabilities assessment

2-2-1-1 Required system survivability measures/goals

2-2-1-2 Analysis/Resolution of vulnerabilities

2-2-1-2-1 Defensive avionics

2-2-1-2-2 Sensors

2-2-1-2-3 Weapons

2-2-1-2-4 Airframe

2-2-1-2-5 Engines

2-2-1-3 Nuclear Hardness Maintenance Plan

2-2-2 Required System Enhancements

2-2-2-1 Redundant systems

2-2-2-2 Masking of flight critical components

2-2-2-3 Observables reductions (IR, RCS, visual)

2-2-2-4 Fire suppressant features

2-2-2-5 Battle Damage Repair plans

2-2-3 Combat Support Structure survivability improvements

2-3 Sustainability

What are my critical "war stoppers" and what do I project as problems?

2-3-1 POS/WRM analysis

- 2-3-1-1 Requirements summary
- 2-3-1-2 Current posture analysis
- 2-3-1-3 Projection of FYDP
- 2-3-1-4 High value/critical items shortfalls

III. WEAPON SYSTEM IMPROVEMENT PROGRAMS

What programs are needed to meet the forecasted shortfalls?

3-1 Sustaining Engineering

- 3-1-1 Summary listing of sustaining engineering programs
 - 3-1-1-1 Aircraft/systems
 - 3-1-1-2 Engines
- 3-1-2 Individual program summaries

3-2 Modification programs

- 3-2-1 Summary listing of modifications
 - 3-2-1-1 Aircraft/systems/software
 - 3-2-1-2 Engines
- 3-2-2 Individual modifications summaries
 - 3-2-2-1 Background of modification including need
 - 3-2-2-2 Deficiency of system
 - 3-2-2-3 Corrective action (R and M measures if appropriate)
 - 3-2-2-4 Additional information
 - 3-2-2-4-1 Structural and/or electronic interfaces
 - 3-2-2-4-2 Related issues - space, power requirements
 - 3-2-2-5 Schedule
- 3-2-3 Fleet resource integration
- 3-2-4 Fleet availability projections
- 3-2-5 Fleet installation schedule

3-3 Replacement Equipment

- 3-3-1 Summary listing of replacement equipment
 - 3-3-1-1 Aircraft
 - 3-3-1-2 Engine
- 3-3-2 Individual replacement equipment summaries
 - 3-3-2-1 Background
 - 3-3-2-2 Deficiency
 - 3-3-2-3 Corrective action
 - 3-3-2-4 Additional information
 - 3-3-2-5 Schedule

3-4 Replenishment Spares

- 3-4-1 Summary listing of replenishment spares
 - 3-4-1-1 Aircraft
 - 3-4-1-2 Engines
- 3-4-2 Individual replacement equipment summaries
 - 3-4-2-1 Background
 - 3-4-2-2 Deficiency
 - 3-4-2-3 Corrective action
 - 3-4-2-4 Additional information
 - 3-5-2-5 Schedule

3-5 AFLC infrastructure requirement forecasts (includes both engine and aircraft requirements)

- 3-5-1 Manning requirements - SPM and direct support

- 3-5-2 Special support facilities
 - 3-5-2-1 Software
 - 3-5-2-2 High tech
 - (Composites, Pave Pillar, Artificial Intel, Very High Speed Integrated Circuits, etc.)
 - 3-5-2-3 Other
- 3-5-3 DPEM program summaries
 - 3-5-3-1 Depot Maintenance
 - 3-5-3-2 Exchangeables Program
 - 3-5-3-3 Software support
 - 3-5-3-4 Other Major End Item Maintenance

IV. FINANCIAL PROJECTIONS

*** What is the plan to meet R and M 2000 goal to reduce cost of ownership and to keep Operating and Support Cost constant? What are my POM, BES submissions by Budget Code? What are the costs of my programs and what are my trade-offs with anticipated funding profiles?***

- 4-1 Engineering requirements forecasts
 - (trade offs/funding priorities/analyses)
- 4-2 Modification forecast
 - 4-2-1 Cost projections- Class IV
 - (trade offs/priorities/analyses)
 - 4-2-2 Cost projections- Class V mods
 - (trade offs/priorities/analyses)
- 4-3 Replacement Equipment
 - (trade offs/priorities/analyses)
- 4-4 Replenishment Spares
 - (trade offs/priorities/analyses)
- 4-5 AFLC Infrastructure requirements
 - (trade offs/priorities/analyses)
 - 4-5-1 Manpower requirements
 - 4-5-2 Facilities requirements
 - 4-5-1-1 Integration Support Facilities
 - 4-5-3 DPEM programs

APPENDICES

A. Weapon System Description

- A-1. Mission/Program Description
- A-2. Operational Inventory/Deployment/Force location
- A-3. MDS descriptions
 - A-3-1 Missions
 - A-3-2 Rules
- A-4 Service life projections
- A-5 Computer applications
 - A-5-1 Software maintenance concept
 - A-5-2 Software - mission correlation
 - A-5-3 Software update requirements
- A-6 Baseline management program summary
 - A-6-1 PDM/Depot maintenance concept/summary
 - A-6-2 Major management activities/status

B. Key Personnel Listing

C. Review Schedule

D. List of Acronyms and Abbreviations

E. Applicable data sources

F. Related Documents

- Avionics Master Plan
- Electronic Combat Action Plan
- ECCM Master Plan
- Test and Evaluation Master Plan
- Generic Logistics Decision Tree
- Statements of Need
- Program Management Plan
- Computer Resources Integrated Support Plan
- Operational/Support Configuration Management Procedures
- Integrated Logistics Support Plan
 - Source: DODI 5000.39, AFR 800-8
- USAF Long Range Logistic Planning Guide (draft)
- R and M 2000 Plan
- Aircraft Structural Integrity Program Master Plan
 - Source: AFR 80-13, AFSC/AFLC Sup 1
- Program Management Directive (PMD)
- Program Funding
- Modification Data Sheets
- Global Assessment
- Air Force 2000
- Interservice Support Agreements
- Logistics Research and Studies Program Document (AFCOLR)
- MAJCOM R and M 2000 Plans
- JCS Master Navigation Plan
- System Operational Concept (SOC) AFR 55-24
- Air Force Lessons Learned Program, AFALC
- Maintenance Concept, AFR 66-14
- Government Industry Data Exchange Program
- Defective Parts and Component Control Program, AFR 800-20
- Aircraft Historical Reliability and Maintainability
 - Data, AFALCP 800-4
- Logistics Warranty Implementation Plan

AFLC Depot Maintenance Posture Plan
AFSC Vanguard plan series
Computation of Requirements for Equipment Type
Items-Follow on Procurement
 Source: HQ AFLC/MMM, AFLCR 57-2
Standard Technical Information File (TIF)
 of Support Equipment MIL-HDBK 300
 Source: HQ AFLC/MML, AFLCR 73-2
Standard Integrated Support Management System
 Source: HQ AFLC/MML, AFSC/AFLCR 800-24
Support Equipment Recommendation Data (SERD)
 Source: LOC/CF, AFSC/AFLCR 800-5
Acquisition of Support Equipment
Evaluation of use of existing or
elimination via technology insertion.
 Source: HQ USAF/RDXM, AFR 800-5
Support Equipment Acquisition Proliferation
Considerations
 Source: AFLC LOC/CFS, AFLCR 800-44
Modification Program Approval and Management
 Source: HQ USAF/LEYY, AF 57-4
Engineering and Technical Services
Management and Control
 Source: HQ AFLC/MMM, AFLCM 66-18